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UNIVERSITY OF ALBERTA

PALYNOLOGY AND AGE OF EARLY TERTIARY BASINS, INTERIOR BRITISH COLUMBIA

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

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DEPARTMENT OF GEOLOGY

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LEONARD VINCENT HILLS, B.Sc., M.Sc.,

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Palynology and Age of Early Tertiary Basins, Interior British Columbia", submitted by Leonard Vincent Hills, B.Sc., M.Sc., in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

ABSTRACT

Palynological and lithologic samples were collected from nine isolated Tertiary localities in south central British Columbia (Princeton, Coalmont, Merritt, Nicola-Mamit locality, Quilchena, Tranquille, McAbee, Williams Lake and Driftwood Creek). Seventy-six spore and pollen species belonging to the following genera are described: Pluraecellaesporites, Phragmosporites, n. gen., Dyadosporites, Inapertisporites, Osmundacidites, Laevigatosporites, Anemia, Azolla, Deltoidospora?, Verrucosisporites, Gleichenidites, Cycadopites, Larix, Tsuga, Picea, Abietineaepollenites, Alisporites, Pityosporites, Podocarpidites, Podocarpus, Phyllocladites, Taxodium, Metasequoia, Cunninghamia, Taxodiaceaepollenites, Betula, Alnus, Carpinus, Castanea, Juglanspollenites, Carya, ?Platycarya, Pterocarya, Tilia, Salix, Tricolpites, Acer, Aesculus, Ericipites, Momipites, Myriophyllum, Pistillipollenites, Potamogeton, Sabal, Psilodiporites, Triporopollenites, Tricolporopollenites, Polycolpites. Seventeen of these are identical to species described from the middle Eocene Green River Formation, Wyoming.

Trogosine tillodont (mammal) remains from the Allenby Formation at Princeton, and 22 K-Ar radiometric dates (range 45 to 53 m.y., average 48) from these and correlative strata indicate that they are middle Eocene in age.

The early Tertiary strata of these basins can be subdivided into three and possibly four plant microfossil zones. From the base upwards they are: Bisaccate "Zone" characterized by 80 percent or more of bisaccate pollen; the Azolla primaeva Zone characterized by the presence of the water-fern Azolla; the Pistillipollenites mcgregorii Zone. This latter zone may be further subdivided into two sub-zones, a lower subzone with Taxodium hiatipites dominance, and an upper with a bisaccate pollen dominance. All three zones are present at Princeton and Coalmont. The Tranquille beds, Williams Lake sediments and the Driftwood Creek sediments belong to the Bisaccate "Zone" and the Azolla primaeva Zone. The sediments at McAbee appear to be correlative with the

Bisaccate "Zone" slightly older or both. The Coldwater beds at Merritt, Nicola-Mamit locality and Quilchena belong to the Pistillipollenites mcgregorii Zone.

Azolla primaeva and Pistillipollenites mcgregorii are the only two palynomorphs which serve as zone indicators. The remainder either are present throughout the section or are too rare to be used for zonation.

There is a correlation of sediment type with the spore and pollen assemblage. Bisaccate forms are dominant in the coarser clastics, whereas Azolla primaeva and Taxodium hiatipites are the dominant forms in the finer shales.

Plagioclase feldspar separates yield radiometric dates in agreement with cogenetic biotite, sanidine and hornblende. Oxyhornblende samples yield dates in agreement with the assigned stratigraphic position (middle Eocene). A single date based on glass shards yielded an age one-half that of cogenetic sanidine. Both plagioclase and hornblende may be used in dating Tertiary events, but shard dates are unreliable.

Paleocurrent directions were southward in the area south of Quilchena.

Palynological evidence suggests that the paleoclimate was subtropical to warm temperate. "Cooler" components of the microfloral assemblage are interpreted as having been derived from upland surfaces.

Lithologic studies suggest that the upland surfaces were formed by granitic rocks, whereas the lowland areas were developed on such rock types as the Nicola Group.

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CHAPTER ONE

INTRODUCTION

Wodehouse (1933) was the first major worker in the field of Tertiary palynology in North America, and his work on the Green River Formation is still one of the most comprehensive to date. Since that time a number of papers on Tertiary palynology have been published, e.g. Wilson and Webster, 1946; Traverse, 1955; Wolfe, 1962; Rouse, 1962; Crickmay and Pocock, 1964. Microfloral lists have been presented by several authors, for example, Hail and Leopold, 1960; Leopold (In Bradley, 1965); and Mathews and Rouse, 1963. It can be safely stated that Tertiary palynology in North America has only begun, and that much valuable information will certainly be forthcoming in future years.

Scope of the Project

The age and correlation of various Tertiary deposits in British Columbia has been the subject of controversy for many years. For example the age of the Allenby Formation at Princeton based on plant megafossils has been variously interpreted as Eocene, Oligocene, late Oligocene, and Miocene. From these beds, insects have been interpreted as having Oligocene or Miocene affinities; mammal (trogosine) remains have indicated affinities with the middle Eocene; and a potassium-argon date has indicated a middle Eocene age. In general, the evidence indicates (Rouse and Mathews, 1961) that the Allenby Formation is middle Eocene in age, and is generally correlative to plant-bearing strata at other localities in central British Columbia, viz., those at Coalmont, Merritt, Kamloops, Williams Lake and Smithers (Driftwood Creek), fig. 1.

The purpose of this thesis is to evaluate the various age assignments of the Allenby Formation, to make a palynological and radiometric correlation with other early Tertiary strata in British Columbia, and to describe the palynological assemblage of this

formation.

Location of Palynological Sections

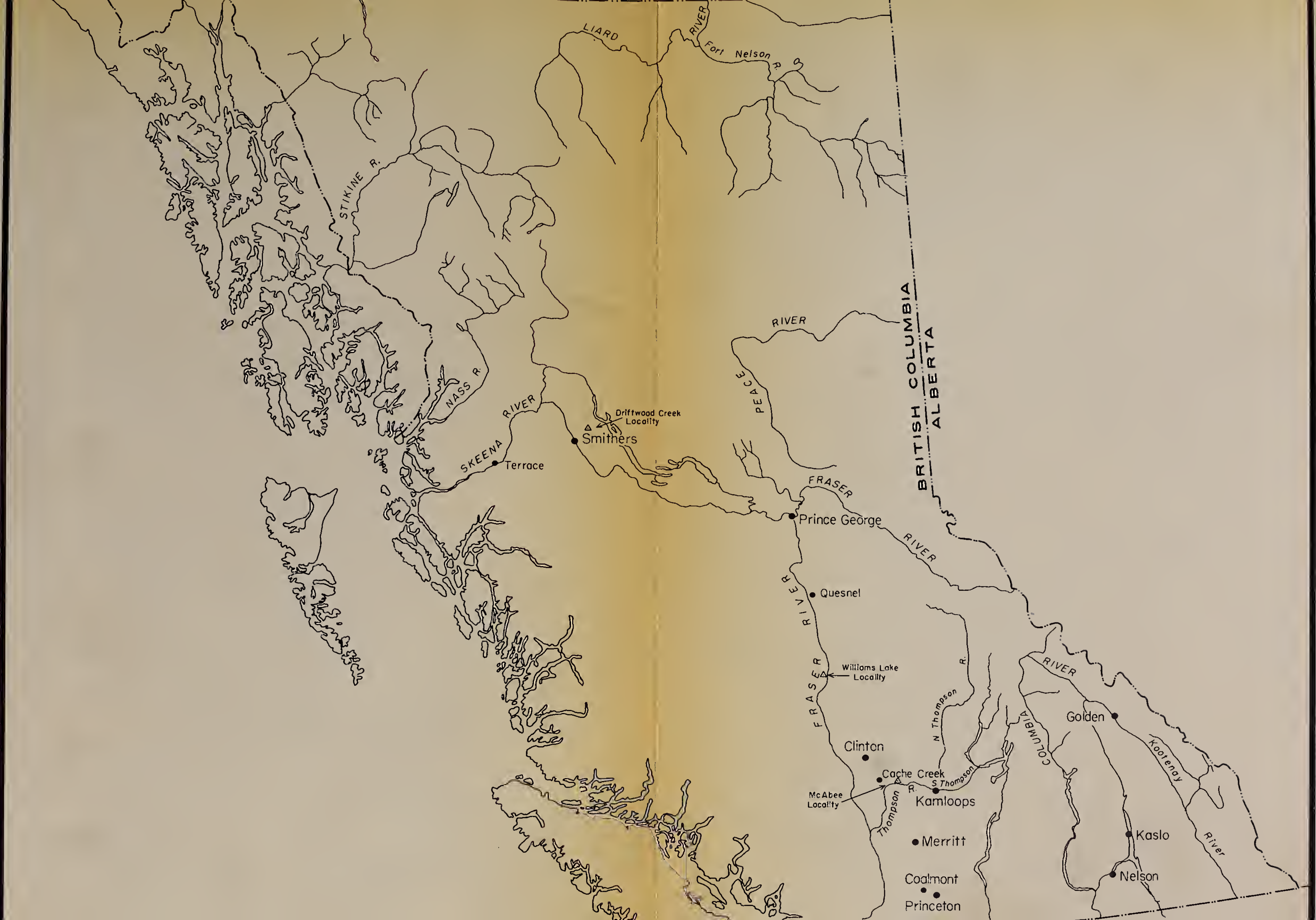
Palynological and lithologic samples were collected from eight sections (fig. 1). These were at Collins Gulch, Tulameen; Coal Gully, Merritt; on the Nicola-Mamit Road 4.5 miles north of the Junction of Guichon Creek with the Nicola River (Merritt); Coldwater beds at Quilchena (Merritt); Tranquille beds in the first gully east of Battle Bluff on the north shore of Kamloops Lake west of Kamloops; McAbee sediments two miles north of McAbee; Williams Lake sediments 3.2 to 3.7 miles west of Williams Lake on the Bella Coola Road; Driftwood Creek sediments seven miles northeast of Smithers.

Location of Samples for Radiometric Dating

Samples for potassium-argon dating were collected at the following sites (figs. 2, 4, 5, 6, 7, 8): Sunday Summit, 24 and 25 miles southwest of Princeton on the Hope-Princeton Highway (AK625 and AK627); 200 feet south of the South Fork of Sunday Creek on the Hope-Princeton Highway (Sunday Creek sanidine); on the Copper Mountain Railway about 3.5 miles south of Allenby (Princeton biotite rhyolite); about 400 feet above the base of the Coalmont sediments on Collins Gulch, Tulameen district (Collins Gulch bentonite); 2.5 miles south of Quilchena on the east side of Quilchena Creek, Merritt district (Quilchena bentonite); 10 feet above the base of the Tranquille beds in the first gully east of Battle Bluff on the north side of Kamloops Lake (Tranquille ash); two miles north of McAbee (McAbee 1 and 2); Driftwood Creek, seven miles northeast of Smithers (Driftwood Creek bentonite).

Summary and Conclusions

Many isolated areas of Tertiary sedimentation have been mapped throughout



BRITISH COLUMBIA
ALBERTA
LIARD
RIVER
Fort Nelson R.
STIKINE R.
NASS R.
SKEENA
RIVER
Terrace
Smithers
Driftwood Creek Locality
PEACE
RIVER
FRASER
RIVER
Prince George
Quesnel
Williams Lake Locality
Clinton
Cache Creek
McAbee Locality
N Thompson
R.
S Thompson
Thompson
Kamloops
Merritt
Coalmont
Princeton
COLUMBIA
RIVER
Golden
Kootenay
River
Kaslo
Nelson

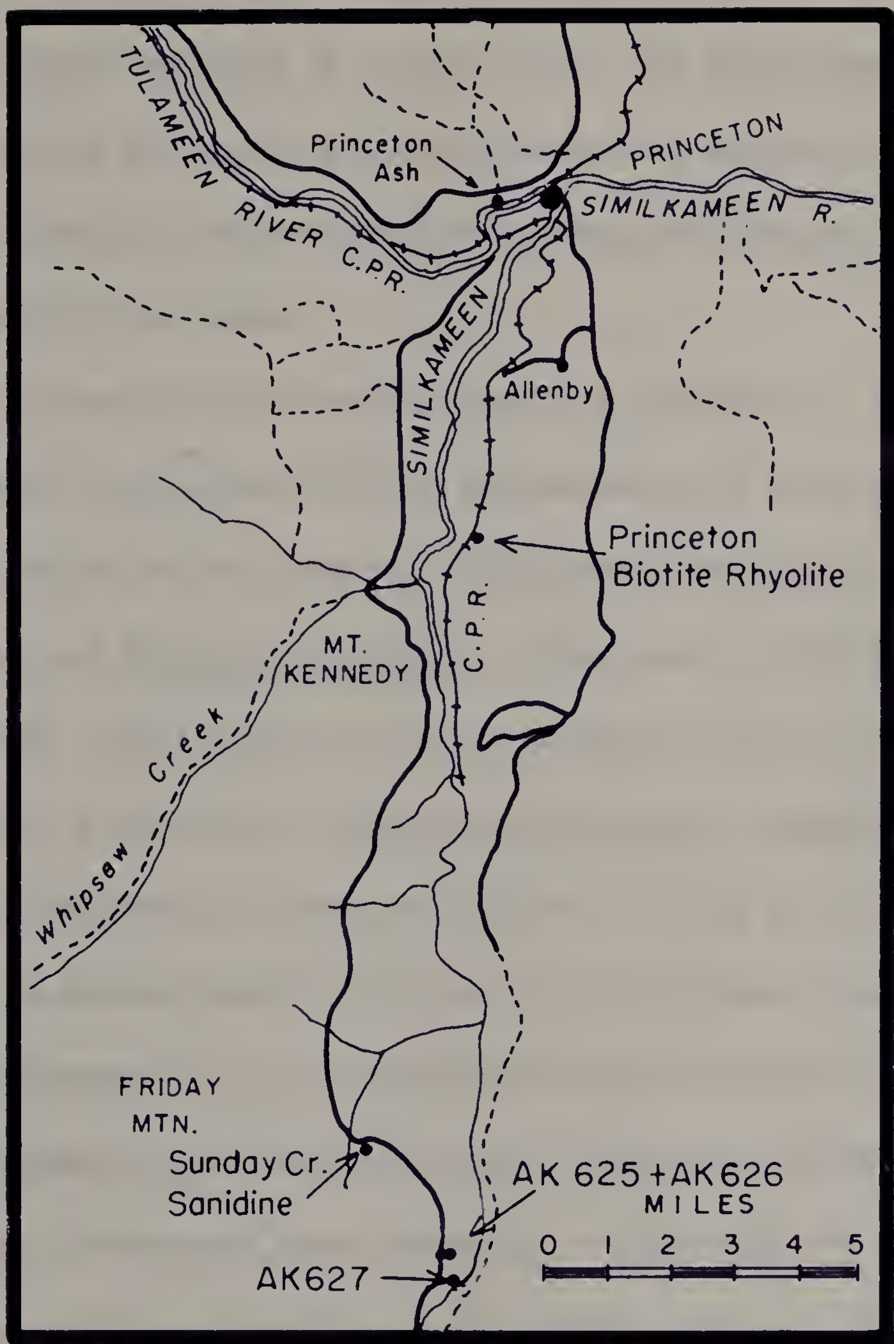


Figure 2. Location of Princeton Biotite Rhyolite, Sunday Creek Sanidine, AK 625 and AK 627.

British Columbia. The age of these deposits has long been a subject of controversy (Rice, 1947). Rouse and Mathews (1961) and Mathews and Rouse (1963) initiated a program of palynological and K-Ar dating in an attempt to settle the correlation and age of these strata. Their work indicates that the Tertiary of the Interior of British Columbia can be divided into two age groups; a middle Eocene sequence of volcanic and sedimentary rocks, and a Mio-Pliocene sequence of similar rocks. The present study is a detailed palynological study of nine basins belonging to the middle Eocene sequence. Palynological studies at Princeton and Coalmont indicate that the sedimentary sequence can be subdivided into three, and possibly four zones.

These zones from the base upwards are as follows: Bisaccate "Zone", characterized by a predominance of bisaccate forms' _Azolla primaeva_ Zone, characterized by the presence of the water fern _Azolla_ in association with many bisaccate types and _Taxodium hiatipites_. This zone is overlain by the _Pistilipollenites mcgregorii_ Zone, which may be further subdivided into two subzones. The lowermost is characterized by a dominance of _Taxodium hiatipites_, whereas the uppermost is characterized by a dominance of bisaccate grains. A study of the remaining sections indicates that they can be placed readily into one or more of these zones, except the strata at McAbee, which appear to be somewhat older than the other localities.

The present palynological evidence indicates that the Tranquille beds, Williams Lake sediments, Driftwood Creek sediments, and possibly the McAbee sediments correlate with the Bisaccate "Zone" and the _Azolla primaeva_ Zone. The presence of _Azolla_ spores in float at Quilchena suggests that this zone is represented at this locality also. The Coldwater beds at Merritt, Nicola-Mamit location, and the uppermost strata at Quilchena clearly belong to the _Pistilipollenites mcgregorii_ Zone. This interpretation that the Coldwater beds are equivalent to the upper Allenby Formation and the uppermost strata at Coalmont is presented for the first time. Previous workers had suggested that the Coldwater beds pre-dated the Kamloops Group.

Both the lithologic and palynologic assemblage indicate extremes of relief. Lithologic studies indicate that the uplands were formed of granitic bodies, whereas the lowlands were formed on less resistant rock types e.g. the Nicola Group.

Hills (in press) concluded that the paleocurrent direction at Princeton was southward. This conclusion is strengthened by studies of correlative beds at Quilchena and Merritt which also indicate a paleocurrent flow to the south. The provenance of the sediments at Coalmont is uncertain, but there is evidence which suggests that the source was to the north and probably in the Merritt-Quilchena area.

The microfloral assemblage suggests that the paleoclimate was subtropical to warm temperate. Rice (1959, p. 3) also arrived at the same conclusion, based on his study of fossil Bibionidae.

The presence of trogosine tillodonts and the 22 potassium argon dates, 14 of which are presented here and eight by Rouse and Mathews (1961), clearly indicate that these strata are middle Eocene in age. Palynologically there is only about one-third of the total pollen correlative with the middle Eocene Green River Formation. With further studies of both areas this low palynological correlation will undoubtedly change. For example Azolla megafossils have been reported from the Green River Formation but as yet the spores have not been described.

There is a direct correlation between lithology and spores and pollen content of the sediment. Coarse sediments are characterized by a dominance of bisaccate forms, whereas the finer shales are characterized by the presence of Azolla primaeva and Taxodium hiatipites. This relationship must be borne in mind when correlating two areas of differing lithologic composition, for example, an area receiving shales as opposed to coarse sandstone and conglomerates.

Unaltered hornblende and plagioclase feldspar give K-Ar radiometric dates in agreement with sanidine and biotite, therefore, they may be used in dating Tertiary strata. A single sample of unaltered (?) glass shards gave a date less than one-half that of cogenetic sanidine and therefore dates based on shards must be treated with caution.

CHAPTER TWO

RADIOACTIVE DATING

The dual decay of K^{40} [to Ca^{40} by beta-decay and to Ar^{40} by K-electron capture] offers two methods of radiometric age dating. The branching ratio strongly favours the formation of Ca^{40}, however this branch has not been used to any extent as a chronometer because of the abundance of Ca^{40} in nature. The disintegration of K^{40} to Ar^{40}, which comprises only 11.2 percent of the total decay, is the basis of the K-Ar method of radiometric dating. For a critical and historical review of the technique the reader is referred to the following Papers: Rankama, 1950; Hamilton *et al.*, 1962; Peterman, 1962; Shafiquallah, 1963.

In recent years the K-Ar method has been successfully applied to dating of sedimentary strata, for example: Folinsbee, Baadsgaard, and Lipson, 1960; Evernden, Savage, Curtis and James, 1964; Mathews, 1963; Rouse and Mathews, 1961; and others.

It is the purpose here to apply the K-Ar technique of dating to Tertiary strata in British Columbia which have been correlated on the basis of palynology and lithology and to evaluate cogenetic: sanidine, biotite and plagioclase; biotite and plagioclase; plagioclase and hornblende; sanidine and volcanic glass shards. All of these have been previously used for dating purposes and the following discussion is a brief summary of the relative merits of each of these minerals.

Sanidine

Pure unaltered sanidine with a low 2V has been found to be very suitable for potassium-argon dating because it retains argon well and has a low level of air contamination (Folinsbee *et al.*, 1960; Evernden *et al.*, 1964; Baadsgaard *et al.*, 1961; Baadsgaard and Dodson, 1965).

Biotite

Under static conditions biotite retains argon well (Goldich *et al.*, 1961) and is a reliable mineral for K-Ar dating. Lowdon (1961) studying the effects of weathering suggested partial chloritization has little effect on the dates. However, Kulp and Basset (1961) have shown that both argon and potassium may be lost from weathered biotites. Baadsgaard and Dodson (1965) indicate that this loss has little effect on the K-Ar ratio. Folinsbee *et al.*, (1960) initially suggested that biotite gave slightly older dates than sanidine but subsequent work by Folinsbee *et al.* (1963), and Shafiquallah (1963) has shown that the reverse is true. It is generally agreed that unweathered biotite is eminently suitable for dating purposes.

Plagioclase Feldspars

Evernden and Curtis (1964) have shown that high argon retentivities are characteristic of plagioclase feldspars of low and high potassium content, whereas, those with intermediate potassium values display lower retention factors. The present evidence suggests that unaltered plagioclase may be useful for K-Ar dating purposes.

Hornblende

Hart (1961) studied radiometric ages on hornblende and biotite across a contact metamorphic zone and found that hornblende retained argon better than biotite. Later (1961b) he studied 12 hornblendes one actinolite and two pyroxenes and found no evidence for excess argon in amphiboles as postulated by Damon and Kulp (1958). Steiger (1964) dated hornblendes from the Gotthard massif. and concluded that dates based on hornblende were in agreement with petrofabric analysis and field relationships however, this point may be open to question as many samples yielded old dates and, therefore, the possibility of excess argon in some could not be ruled out. Peterman (1962) found that there was good agreement between hornblende and biotite and that differences in dates appeared to

be random. Although, there is a suggestion that hornblendes may contain an excess of argon the present evidence indicates that hornblende may be used for dating.

Volcanic Glass

Baadsgaard and Dodson (1965) state that even when relatively pure glass shards can be obtained the argon loss is relatively severe and that dates obtained have been one-half of the Holmes time scale equivalent. Schaeffer et al., (1961) suggest that unaltered glass may give good dates. Curtis (in Schaeffer et al.,) states that under favourable conditions, good radiometric age concordance with biotite and sanidine was found with samples as old as Lower Miocene. However, very poor concordance was noted with others. Microscopic examination indicated that all samples giving erroneous dates were devitrified. The present evidence would indicate that radiometric age based on volcanic glass are not too reliable.

Results of K-Ar Dating

Six sanidine, five biotite, two hornblende, five plagioclase and one volcanic glass were dated by the K-Ar method. In the following paragraphs individual minerals are evaluated for their usefulness in dating Tertiary events and the age and correlation implications of these dates are discussed. Table 1 presents the dates obtained in Tabular form and lists previously published dates on early Tertiary Strata in British Columbia Fig. 3 indicates the relative stratigraphic position of the K-Ar samples and the dates obtained.

TABLE 1

RADIOMETRIC DATES OF EARLY TERTIARY STRATA IN BRITISH COLUMBIA.
Those preceded by an asterisk are from Mathews (1963).
Cogenetic combinations are as follows: AK625 and AK 626; AK630 and AK631; AK632 and AK633; AK636, AK637 and AK638; AK640, AK641, AK642, and AK656.

Ak. No.	Description	K_2O	Percent Radiogenic	Date M.Y.
625	Hornblende, Sunday Summit S.S.V.3	0.67	68.4	50.2
626	Plagioclase, Sunday Summit S.S.V.3	0.52	46.4	46.7
627	Hornblende, (Epidote) Sunday Summit S.S.V.4	0.66/0.66	28.7	48.1
629	Andesine, McAbee #2	0.62	73.8	48.9
630	Sanidine, Quilchena	6.28	86.8	48.9
631	Glass Shards, Quilchena	1.82	24.3	21.9
632	Biotite, Princeton Biotite, Rhyolite	5.81	96	50
633	Andesine, Princeton Biotite Rhyolite	.60	75.2	46
634	Sanidine, South Fork Sunday Creek	4.23	93.7	45.7
635	Sanidine, South Fork Sunday Creek	6.52	79.9	47
636	Andesine, McAbee #1	1.18	58.6	51.4
637	Biotite, McAbee #1	7.92/7.98/8.01	85.1	57.4
638	Sanidine, McAbee #1	3.87	81.8	67.4
640	Oligoclase, Tranquille	1.57	84.4	51.1
641	Sanidine, Tranquille	8.17	94.9	48.6
642	Biotite, Tranquille	7.64		51.2
643	Biotite, Collins Gulch	5.30	83.3	46.8
645	Sanidine and Chert, Driftwood Creek	2.45	87.9	

Ak No.	Description	K_2O	Percent Radiogenic	Date M.Y.
656	Biotite, Tranquille	7.87	83.3	47.9
*99	Biotite, Princeton Ash	8.15		48+2
*112	Biotite, Rock Creek Ash	5.63		49+
*117	Biotite, Mt. Savona "trachyte"	7.0		45+2
*118	Biotite, Tranquille "dolerite"	7.06		49+2
*150	Biotite, Pulaskite Porphyry Kettle River	6.48		48+2
*151	Biotite, Dacite Joe Rich Creek	7.92		46+2
*302	Biotite, T-Allin Dacite	6.73		53+2
*395	Biotite, Endako Lava Hicks Hill	6.45		48+2

Reproducibility of Results

The present set of K-Ar runs were not designed to test reproducibility of dates. However, two size fractions of sanidine (AK634 and AK635) from a lapilli tuff on the south fork of Sunday Creek yielded dates of 46.9 m.y. (coarse fraction) and 45.7 m.y. indicating reproducibility of 1.2 m.y. Shafiquallah (1963) lists, multiple runs indicating general reproducibility of 1.2 to 1.7 m.y. in 50 to 60 m.y. A biotite from the upper Ardley Coal seam suggested reproducibility of 3.7 m.y. but this biotite had apparently lost argon as cogenetic sanidine gave a date of 63 m.y. as compared to an average of 51.2 for the former. Folinsbee *et al.*, (1963, p. 75) indicate a 1.1 m.y. reproducibility on a sanidine yielding an average radiometric age of 94 m.y. Thus the reproducibility on repeat runs is very good and well within $\pm$ 2 percent of the average of a single mineral.

The maximum error of analytical precision reported by Shafiquallah (1963) was of the order of three to five percent. This figure involved errors introduced by potassium and argon analysis. There is no reason to believe that the results of the present study should differ significantly from this value, therefore a factor of $\pm$ 2.5 m.y. should encompass any errors in analytics.

The problem of stratigraphic position of the source materials for minerals dated is not taken into consideration in the above three to five percent. In view of the agreement of these dates with palynological correlations errors in stratigraphic assignment are probably insignificant.

Discussion of Radiometric Dates

Six sanidine dates were run during this study. Of these, four (AK630, AK634, AK635, AK641) agree with the stratigraphic assignment and previously K-Ar dated samples, and one (AK638) gives a date of 67.4 m.y. which is too old on the basis of stratigraphy and correlative K-Ar dates. An impure sanidine AK645 gave a date of 170 m.y., which is high by a factor of 3.5. The presence of chert in the sample suggests

that the sanidine may have been introduced from an older horizon.

Biotite

Five biotite samples (AK632, AK637, AK642, AK643, AK646) were run and all, with the exception of AK637, give dates in accordance with stratigraphy and previous K-Ar dates. Sample AK637 appears to give too old a date. The explanation is not known.

Hornblende

Two samples of oxyhornblende (AK625 and AK627) were run. These gave dates in accord with the stratigraphic position of the sample and with correlative K-Ar dates from biotites and sanidine. This suggests that unaltered low potassium hornblendes can be used in dating Tertiary strata.

Plagioclase Feldspar

Five (AK626, AK629, AK633, AK636, AK640) plagioclase feldspars ranging from An_{25} to An_{55} in composition were run. All yielded dates which are in agreement with cogenetic minerals or stratigraphic correlation. For example, the Tranquille oligoclase yielded a date of 51.1 m.y., whereas cogenetic biotite gave a date of 50. m.y. and sanidine gave 48.6 m.y. A biotite date of 50 m.y. (AK632) corresponds closely to a date of 49 m.y. (AK633) on high andesine or low labradorite (An_{45}-An_{55}). This is in agreement with the findings of Evernden et al. (1964a) that unaltered plagioclase may be used for dating Tertiary strata.

Volcanic Glass

Only a single shard separate was run (AK631). This sample yielded a date of 21.9 m.y. as compared to 37 m.y. on cogenetic sanidine. A petrographic study indicated that the shards appeared unaltered, and therefore, should have given an older

date. This combined with the findings of Baadsgaard and Dodson (1964) indicates that volcanic glass shards are not suitable for dating purposes.

The radiometric dates obtained during the course of this study range from 46 to 51 m.y., excluding the anomalous dates given by samples AK631, AK637, AK638, and AK645. This is in good agreement with the dates presented by Rouse and Mathews (1961) and Mathews (1963) which range from 45 to 53 m.y. and average 48 m.y. The present data are inadequate to demonstrate conclusively that the range of dates is due to differences in stratigraphic position. At Princeton a biotite and a plagioclase from a lava about 600 feet below the base of the Allenby Formation yielded dates of 50 and 49.4 m.y. respectively. Rouse and Mathews (1961) obtained a K-Ar date of 48 m.y. on biotite from an ash interbedded with the overlying Allenby Formation. This older average age (49.7 m.y.) of the Princeton biotite rhyolite is in agreement with the relative stratigraphic position of the two samples. At Tranquille the average of two biotite dates (AK656, AK642) a sanidine (AK641) and an oligoclase (AK640) is 49.7 m.y. This corresponds roughly to a date of 49.0 m.y. obtained at the same locality by Rouse and Mathews (1961) but some 300 to 500 feet higher in the section. It is noteworthy that a biotite, (AK656) yielded a date of 47.9 m.y., 1.1 m.y. less than the 49 m.y. from the overlying biotite. Further, ash beds associated with the Princeton-Black and Collins Gulch coal seams correlated on a palynological basis yielded dates of 48 m.y., 47 m.y. The evidence suggests that although the possibility of stratigraphic position may have bearing on the dates here presented, analytical precision may account for much of the spread.

The radiometric age data presented here combined with that previously presented by Rouse and Mathews (1961) and Mathews (1963) clearly indicate a middle Eocene age for these strata whether one uses Funnell's (1964) or Kulp's (1961) time limits for the subdivision of the Tertiary.

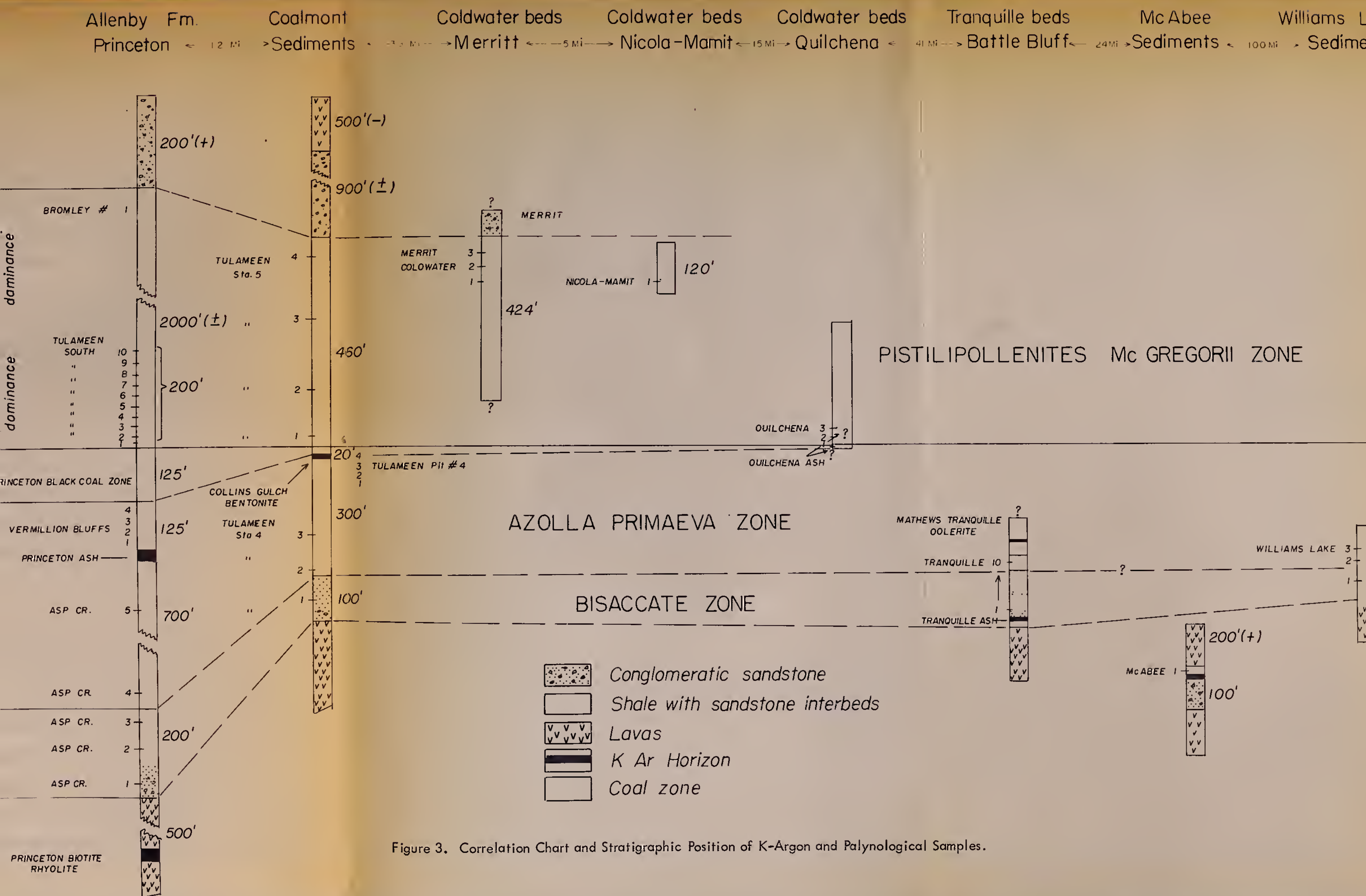


Figure 3. Correlation Chart and Stratigraphic Position of K-Argon and Palynological Samples.

CHAPTER THREE

STRATIGRAPHY

Sedimentary and volcanic rocks of early Tertiary age occur in isolated basins throughout British Columbia. These strata are dominantly volcanic rocks of a wide range of composition (Taylor et al. 1965). However, thick sequences of sediments are known, e.g. Princeton, Coalmont, Merritt and Quilchena. Locally thin lenticular bodies of sedimentary rock are interbedded with volcanic rocks, e.g. Tranquille and McAbee. These sediments are composed of boulder to granule conglomerates, sandstones, shales, pyroclastic rocks, coal, locally fresh water limestone, and diatomite. In the Interior of British Columbia these sediments are of fluvio-lacustrine origin (Shaw, 1952, and others). Correlations of these sedimentary basins are hampered by the scarcity or absence of diagnostic fossils, facies changes and poor exposures. Poor exposures, facies changes and incomplete knowledge of structure even limit correlations within a single basin. The following discussion is a brief description of the lithologies encountered at the various localities studied. Because of poor exposures and common facies no standard stratigraphic section can be drawn even within a single sedimentary basin.

Allenby Formation, Princeton

Shaw (1952a, p. 8) named the Allenby Formation after exposures on the Similkameen River near Allenby. He states that it has a maximum exposed thickness of 3500 feet, and consists predominantly of massive crossbedded granule to pebble conglomerate, sandstone, shale with intercalated coal and bentonite. This unit rests conformably on Tertiary volcanics or unconformably on pre-Tertiary strata, principally the Triassic Nicola Group. He states that it is in part unconformably overlain by lavas. Many of the exposures mapped by Shaw as overlying the Allenby Formation undoubtedly belong to the underlying Tertiary volcanic rocks. The Tertiary volcanic rocks on the

Tulameen River west of Princeton; those crossing the coalfield north of Princeton; and a third series of outcrops at the southern end of the coalfield. Lavas outcropping at the northern end of the coalfield and along the east, immediately north and south of the Similkameen River may belong to a post-Allenby sequence. Those at the northern end of the coalfield rest conformably on 700 feet of coarse conglomerates and sandstones of the Allenby Formation. It is not possible to state that they post-date the Allenby Formation because the entire formation is not present at this point.

It is impossible to give a complete stratigraphic description of the Allenby Formation because much is unexposed. In general, the Allenby can be divided into a lower and upper unit (Hills 1962; in press). Rocks of the lower unit consist of coarse breccias to lithic sandstones; these give way to shales, bentonitic shales, a few stringers of coal, and fresh-water limestones (at Vermilion Bluffs on the Similkameen River). This lower unit locally exceeds 1000 feet in thickness. The Princeton Black Coal seam, which is the lowest major coal seam, is used as the upper limit of the lower unit. Above the Princeton Black Coal seam the strata of the upper unit consist of more than 2000 feet of shale, interbedded coal and sandstone lenses. The sandstone lenses increase in number and thickness upward.

Hills (1962; in press), after a detailed study of cross-stratification and minerals, concluded that the bulk of the sediments of the Allenby Formation were derived from the Osprey Lake Intrusion to the northeast of the coalfield.

About 50 samples of shale were collected, and a palynological study was undertaken by the writer as an M.Sc. Thesis at the University of British Columbia (1962).

Coalmont Sediments

The name Coalmont sediments is here applied to sediments referred to as the "coal-bearing formation" by Shaw (1952b, p. 2). The Coalmont sediments conformably overly and are locally interbedded at the base, with a thick sequence of Tertiary volcanic

rocks on the west and northwest. To the east and south they lap onto rocks of pre-Tertiary age. They are unconformably overlain by up to 500 feet of flat-lying volcanic rocks.

The Coalmont sediments are not well exposed, but outcrops on Collins Gulch are adequate to determine the major lithologic characteristics. The lowermost 100 feet consist of indurated conglomeratic sandstone which becomes progressively finer upwards. This in turn is overlain by about 300 feet of shale and silty to sandy shale with sandstone interbeds. About 400 feet stratigraphically above the base, a four-foot coal-seam is exposed on the east side of the creek. This is followed by 460 feet of shale with several coal seams in the lower 260 feet (Shaw, 1952b, p. 2). During the present study only scattered shale outcrops were observed in this interval. The shale-coal section is overlain by coarse-granule to pebble-conglomerates and sandstones which reach 1500 feet in thickness in the central part of the basin.

Preliminary thin-section studies of the basal sandstones indicate that they are composed of rock fragments derived from a volcanic terrane and were probably derived from the underlying Tertiary volcanic rocks. The upper sandstone and conglomerate unit is readily distinguishable from the lower sandstones on the basis of composition. Petrographic studies indicate that only 30 percent or less of the detritus consists of rock fragments derived from a volcanic terrane. The other constituents are plagioclase, microcline, orthoclase and quartz grains which have been derived from an igneous intrusive. It is not known which of the surrounding intrusives contributed the coarse clastics.

Samples for palynological studies were collected at all shale outcrops on Collins Gulch, in the open pit mine at Blakeburn, and in several coal-prospect trenches along the western margin of the coalfield.

Figure 4. Location of Coalmont Sediments.

Merritt Coldwater Beds

Although outcrops of these beds were too poor to warrant measurement, three shale samples for palynological study and several sandstone samples for petrographic study were collected in Coal Gully and adjacent slopes southwest of Merritt. The stratigraphic relationship of these samples was indeterminable. Cockfield (1948, p. 31) states that Dawson measured 424 feet of strata in this gully containing four coal seams. The sediments consist of alternating coarse conglomeratic sandstone, silty to sandy shale, and coal.

A preliminary thin section study indicated that the coarse clastics are composed predominantly of feldspar and quartz with only minor amounts of rock fragments. The composition indicates that the sediments were mostly derived from a granitic terrane.

Cockfield (1948) mapped scattered outcrops of Coldwater sediments extending up the Nicola River from Merritt to Nicola. A tongue of sediments which extends northwestward from Nicola to the Guichon Batholith suggests that this batholith was the source of the arkose in the Merritt area. A paleocurrent direction to the southeast is implied.

Nicola-Mamit Coldwater Beds

Cockfield (1948, p. 31) states that the occurrence of Coldwater beds on Guichon Creek is based on two small outcrops, and considerable float which appears in the glacial drift.

During the course of the present study, a single outcrop was found in a small gully to the east of the Nicola-Mamit road, 4.5 miles north of the junction of Guichon Creek with the Nicola River. A total of 60 feet of strata was measured. The basal 20 feet consists of shale with interbeds of coarse sandstone, whereas the upper 40 feet is predominantly sandstone with interbeds of shale. The sandstone is an arkose composed of 40 to 50 percent feldspar, 40 percent or more of quartz, and the remainder chert and volcanic rock fragments. The composition of the sandstone indicates granitic provenance.

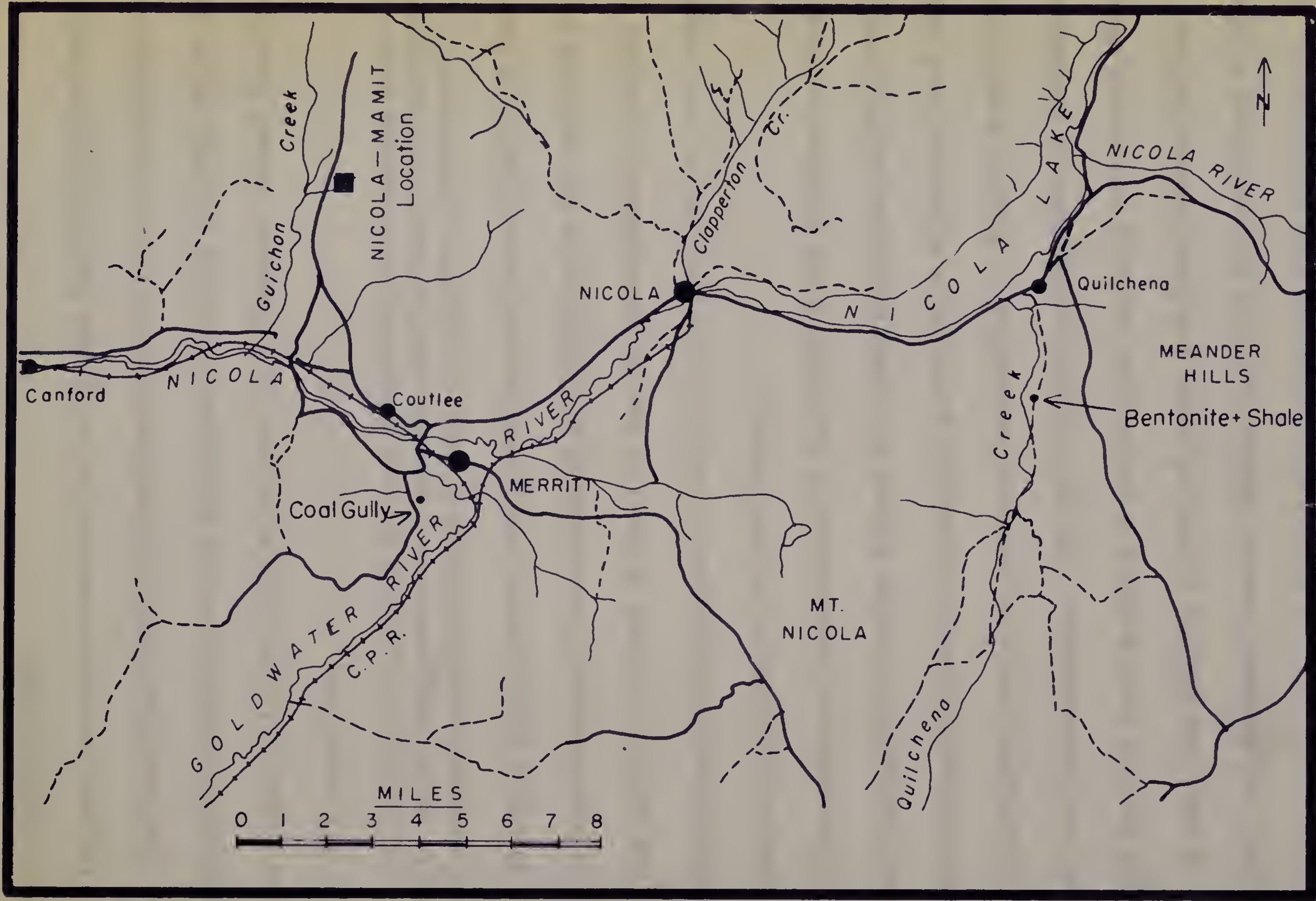


Figure 4a. Location of Coldwater beds at Coal Gully, Quilchena and on the Nicola Mamit Road.

Three shale samples for palynological studies were collected from this locality, two from the basal shale, and a third from shale lenses in the upper 40 feet of sandstone.

Quilchena Coldwater Beds

The section was not measured at Quilchena because none was adequately exposed. Shale samples were collected from about 40 feet of interbedded shales, coaly shales and arkosic sandstones at the abandoned coal-mine workings on the east side of Quilchena Creek, 2 1/4 to 2 1/2 miles south of Quilchena. About these beds, Cockfield (1948, p. 32) states that:

> "A section in a gully on the east side of the creek exposes about 400 feet of sediments in which conglomerate and conglomeratic sandstone make up probably 50 percent of the beds, sandstone about 40 percent, and shale the balance".

Strata of the Coldwater beds were observed to rest directly on the Nicola Group at a locality about five miles south of Quilchena on the east side of Quilchena Creek. The section consisted of about 20 feet of coarse pebble to boulder conglomerate. The phenoclasts were derived from a volcanic terrane and are of local origin, probably having been derived from the Nicola Group.

The sandstones associated with the shales at the old mine workings are arkoses. Preliminary petrographic studies showed that these sandstones contain: feldspars (plagioclase and microperthite) 40 to 50 percent; quartz 30 to 40 percent; and rock fragments (chert and extrusive volcanics) make up the remainder. Several granitic pebbles were collected from the sandstones. The grain size and composition of the pebbles is identical to those of granitic rocks exposed to the north of the basin and around Nicola Lake.

A small but definite outcrop of arkose was found midway between those mapped by Cockfield and the small area of intrusive rocks on the south shore of Nicola Lake. It is probable that the arkose at Quilchena was derived from this intrusion, implying a paleocurrent direction to the south.

Tranquille Beds

The term Tranquille beds was used by Dawson (1896) and Cockfield (1948) to describe sedimentary rocks interbedded with lavas of the Kamloops Group.

The writer measured a partial section of the Tranquille beds in the first gully east of Battle Bluff on the north shore of Kamloops Lake. This section was chosen because Mathews obtained a potassium-argon date from biotite in the overlying volcanic rocks, and also because the writer located a biotite-rich bentonitic ash 10 feet above the base of the section at this point. Exposures in the upper half of the section are very poor.

A total of 110 feet of section was measured, consisting of shales, sandy to silty shales, siltstones, and fine to medium grained lithic sandstones. The upper part of the section is not exposed but the total thickness at this point could not exceed 200 feet. In thin section the standstones are composed predominantly of volcanic rock fragments probably derived from the underlying Kamloops Group.

McAbee Sediments

The name "McAbee sediments" is applied here to the strata which outcrop on the north slope of the Thompson River two miles north of the Canadian National Railway station of McAbee. They outcrop two miles west and half a mile north of the Battle Creek crossing on the Cache Creek-Kamloops Highway. These sediments form a west-trending lens-shaped body about half a mile long and 100 feet in maximum thickness. They are underlain and overlain by lavas and volcanic breccias of the Tertiary Kamloops Group.

A section was measured in a small gully at a point where the beds are 100 feet thick. They consist of a basal 80 feet of coarse pebble to boulder conglomerate which becomes finer upwards, and grades through coarse sand with pebble stringers to fine sand. This is overlain by 20 feet of carbonaceous, silty shale, paper shale, bentonite and bentonitic ash. Well preserved plant megafossils, insects and fish are found in this part

nt
2000
1500
2000
2000
Battle Bluff
Tranquille sediments
Tranquille Ash
Tunnel
C. N. R.
O O P S LAKE
1500
1500
2000
2500
3000
2000
2000
BATCHELOR HILL
1500
C. P. R.
THOMPSON RIVER
NORTH THOMPSON RIVER
ediments, Battle Bluff Area.
IN MILES
1
2
3

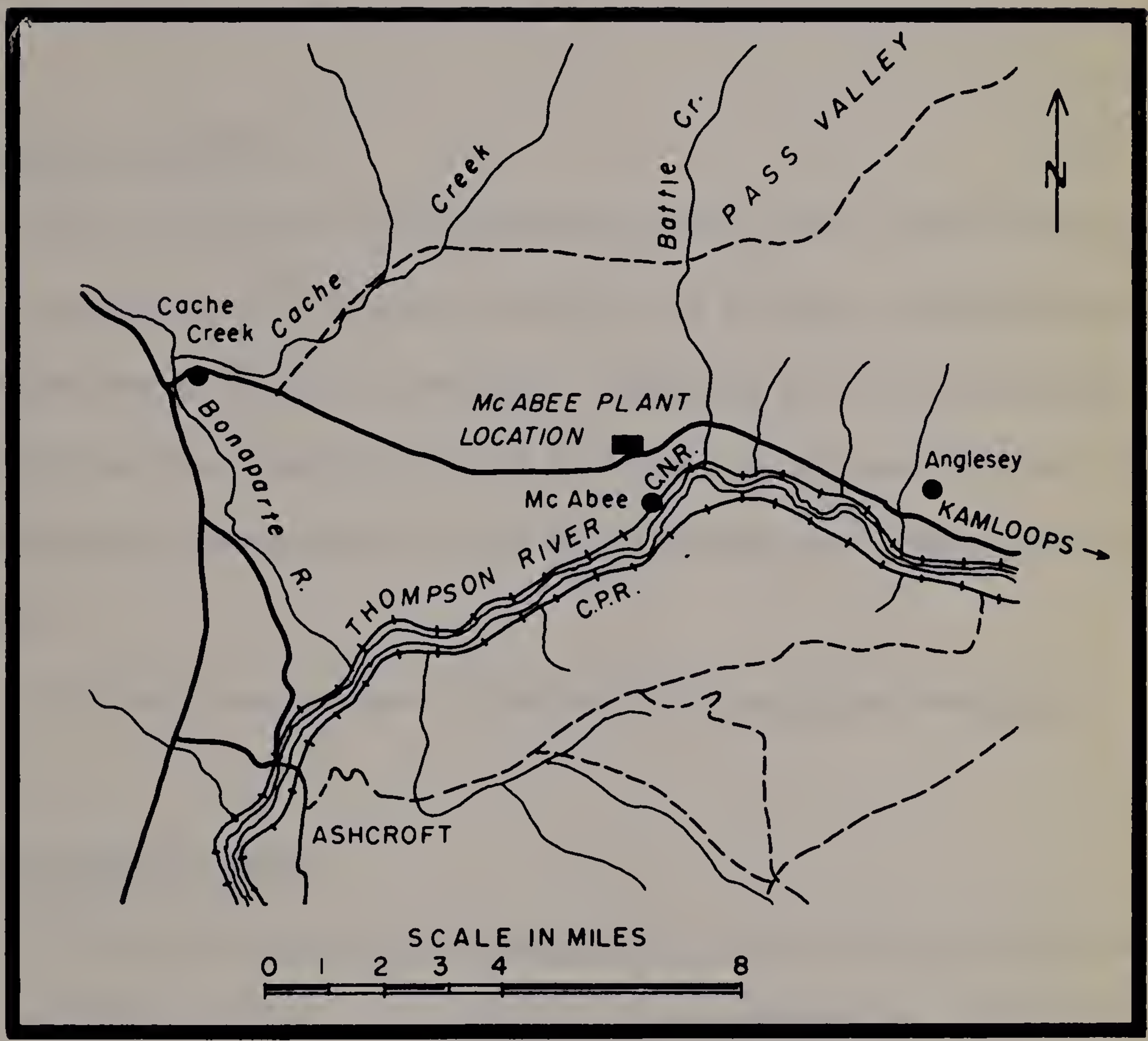


Figure 6. Location of McAbee Sediments.

of the section, whereas only fragments of carbonized stems are present in the basal 80 feet.

The phenoclasts of the conglomerate and the sand-sized particles have been derived from the lavas of the Kamloops Group. Many of the large boulders are only sub-rounded, indicating little transport.

Two channel samples of the uppermost 20 feet were collected for palynological analysis.

Williams Lake Sediments

The name Williams Lake sediments is here used for the first time to designate a small area of Tertiary sedimentary strata on the Williams Lake-Bella Coola Road, 3.2 to 3.7 miles west of Williams Lake, B.C. Exposures of this unit are restricted to road-cuts and borrow pits. The thickness of the section is unknown, but may exceed 200 feet. The sediments are predominantly brown to grey shales with interbedded diatomite and bentonite.

Five shale samples were collected for palynological analysis.

Driftwood Creek Sediments

The name Driftwood Creek sediments is here applied to Tertiary sediments which outcrop on Driftwood Creek, seven miles northeast of Smithers, British Columbia. Mention of the rocks was made by Hanson (1924, p. 21a), and they were previously mapped by Armstrong (1944). A composite section was measured from outcrops on the north and south sides of the creek about midway between the first two road bridges. The strata consist of a basal 20 feet of pebble to cobble conglomerate with sandstone and coal stringers overlain by 100 feet of laminated, brown to grey shale, bentonitic shale, bentonite and minor amounts of sandstone. The pebbles and cobbles are composed of well-rounded, indurated shale (argillite) and rocks of volcanic origin, probably derived

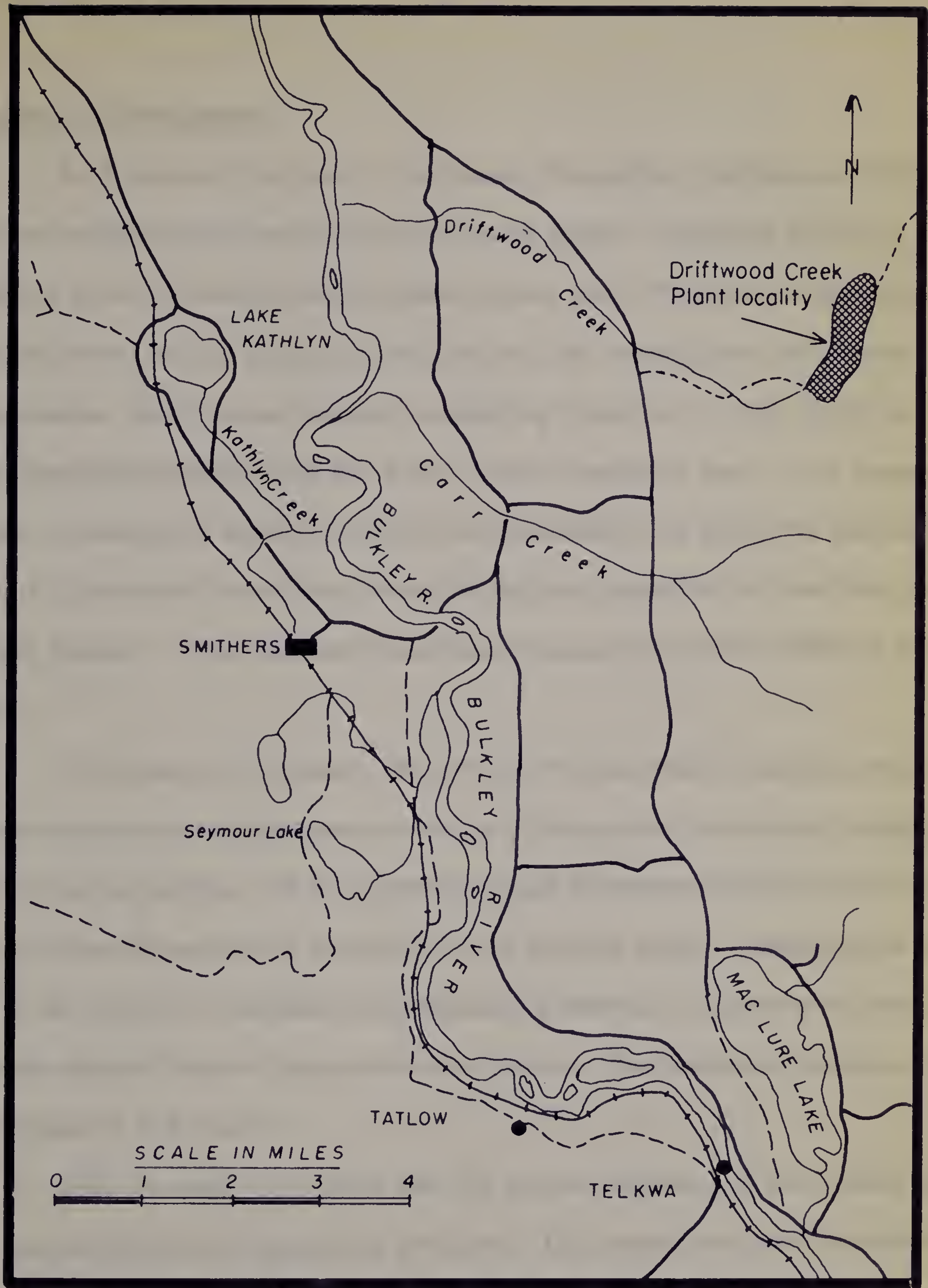


Figure 7. Driftwood Creek Plant Locality.

from the underlying Hazelton Group.

Samples for palynological analysis were collected at ten foot intervals through the shaly part of the section.

Discussion of Stratigraphy

At Princeton, Coalmont, Quilchena, Tranquille, McAbee and Driftwood Creek, the basal sediments are coarse detritus of local origin. Cockfield (1948, p. 31) in reference to the Coldwater beds at Merritt states that: "The beds immediately overlying the rocks of the Nicola group (sic) are derived very largely from their waste, and consist of coarse, poorly sorted material resembling a breccia". Daly (1912, p. 398) stated of the basal arkose-breccia of the Kettle Valley Formation that: "It is composed of angular to subangular blocks of diorite and granodiorite on which the breccia lies, so that it is likely that few or none of the blocks have travelled far from their parent Tertiary ledges". These accumulations were interpreted by Hills (1962) as reworked talus debris.

At Princeton, Coalmont, Merritt, the Nicola-Mamit location, and at Quilchena the sandstones and conglomerates at the top of the section are arkoses, implying a granitic-source terrane. At all locations except Coalmont the arkoses are very pure, and more than 90 percent of the detritus is of granitic origin. Sandstones in the Upper part of the section at Coalmont are composed of detritus, 70 percent or more of which has been derived from an igneous intrusive source. The remainder consists of volcanic rock fragments and chert.

Hills (in press) concluded that the arkosic sediments of the Allenby Formation were derived from the Osprey Lake Intrusion. The present work indicates that the arkosic sediments at Quilchena were derived from the intrusion north of Nicola Lake, whereas those at Merritt and the Nicola-Mamit Road location were derived from the Guichon Batholith. The provenance of the arkosic sediments at Coalmont is uncertain,

but the high percentage of volcanic detritus and chert suggests a more distant source than at any of the other localities. Rice (1947) mapped a series of elongate areas of Tertiary outcrops which extend southward from the Merritt area towards Coalmont. It is possible that the streams that deposited the sediments at Merritt continued southward as far as Coalmont, and that they deposited sediments in both areas. This could have provided a source for the impure arkosic sediments at Coalmont.

Paleocurrent directions at the other localities are unknown. At Tranquille and McAbee and sandstones and conglomerates are of local origin, derived from lava flows.

Former extent of Tertiary Deposits

The former extent of these deposits is difficult to ascertain. At Princeton it was noted in coal mine workings (Shaw, 1952) that the Princeton Black Coal seam became dirty and decreased in thickness to the east, and on the west decreased from a zone more than 120 feet thick to a single workable seam five feet thick. On the Tulameen River west of Princeton, and again on Summers Creek at the north end of the coalfield, Allenby Formation sediments can be seen to lap onto rocks of the Triassic Nicola Group. On the east they lap onto the Osprey Lake Intrusion. This suggests that the former extent of the Princeton Coalfield was not much greater than it is today.

At Merritt, Cockfield mapped a number of isolated areas underlain by rocks of the Coldwater beds. This suggests that the area from Merritt to Quilchena to Courtney Lake may have been extensively covered by Tertiary rocks, which have subsequently been removed by erosion.

In all other areas, data are inadequate to postulate the former extent of the Tertiary strata.

The age of the Allenby Formation

The present evidence indicates that the Allenby Formation is of middle Eocene age. However, the age of the Allenby and related Tertiary strata throughout British Columbia has long been the subject of controversy. Scudder (1895, p. 6) makes the following comments on fossil insects collected by Dawson:

"From the insect data one can make no strong assertion regarding the relative age of the deposits in which they occur, but there are one or two points to which it may be well to direct attention. One is the fact that nearly all the generic groups represented are so far as known extinct; even the few which are here placed in existing genera, -- *Enchophora*, *Ricania*, *Coelidia*, *Cercopis*, *Aphrophora*, -- are in nearly every case so placed only provisionally from the incompleteness of the specimens found; this would surely seem to indicate a relatively great age, at least as old as the oligocene. Another is the reference of a few, generally with certitude, to genera, -- *Cerancon*, *Sbenaphis*, *Palecphora*, *Palaphrodes*, -- known otherwise only from American beds referred to the oligocene; and besides these the only species elsewhere recorded is found likewise in the oligocene. The last fact, however, looks in a different direction, for the cercopid element of the fauna, and as we have seen its most important component, shows a distinct resemblance to that of Radoboj in Croatia, which is regarded as middle miocene".

Dawson (1894, p. 75-76B) adopted the view that these strata were Oligocene or later Eocene, basing his opinion upon the results of insect determinations by Scudder (publ. 1895).

Penhallow (1906) considered that plant megafossils from the Kettle Valley area of British Columbia correlated with the strata at Princeton, Quilchena and Merritt. He clearly states that the flora has strong affinities with the Green River Formation, but concludes that those of Kettle Valley are of Oligocene age.

Russell (1935, p. 54-55) described and illustrated two teeth of *Trogosus minor* from the Allenby Formation at Princeton. Of the age significance of these teeth he states (p. 55) that:

"The order Tillodontia, to which the genus and species belongs, is a primitive group of uncertain affinities, appearing first in the Late Paleocene and apparently becoming extinct in the Eocene. The family Tillotheridae was known only from the Bridger stage of Wyoming and the Tertiary (probably Shark River Eocene) of New Jersey. It appears highly probably, therefore, that this family is confined to the Middle Eocene, and the British Columbian specimen is dated accordingly".

Gazin (1953, p. 35) suggested that the original material for the definition of *T. minor* was inadequate and that it can be matched to material of *T. hyracoides* or

_T_. _castoridens_. This, however, does not affect the stratigraphic assignment of this specimen, as the genus _Trogosus_ was limited to the middle Eocene.

Rice (1947, pp. 29-31) briefly summarized the current ideas on the age and correlation of the Allenby Formation, which he then referred to as Princeton sediments Of the age conflict, he states (p. 31):

"Some conflict, therefore, exists in attempts to fix the age of the Princeton group as between the evidence of the fossil plants and insects and that of the mammal tooth. There is the bare possibility that the Princeton coal basin contains sediments of both ages, separated by an unconformity that has not yet been recognized, but this explanation is improbable. The final solution of the problem will have to await further study, but in view of the cumulative evidence of the plant and insect material that has been made available, the younger age has been provisionally accepted".

Shaw (1952, p. 6) named the Allenby Formation and assigned it to the Oligocene, hereby following Rice.

Gazin (1953, p. 43) described a fossil mammal jaw from the Allenby Formation as _Trogosus_? _latidens_. Of the identification he states:

"It certainly contains the largest tillodont lower teeth known, a size entirely appropriate for _T_.? _latidens_; however, the lingual and bucal surfaces of the teeth appear to converge dorsally somewhat more rapidly than, for example, in _Trogosus_ _hyracoides_, suggestive rather of _Tillodon_ _fodiens_. The Canadian specimen is much too large to be referred to _Tillodon_ _fodiens_ and in the absence of associated upper and lower teeth is retained tentatively and questionably in _T_.? _latidens_".

This is the same assignment he gives a specimen from the Cathedral Bluffs Tongue of the Wasatch Formation. As _Tillodon_ has the same geologic range as _Trogosus_, the re-assignment at a future date of the Princeton fossils to that genus would not affect the middle Eocene age assignment for the Allenby Formation.

Arnold (1955a) redescribed _Azolla_ _primaeva_ (Penhallow) from the Allenby Formation and assigned it to the Oligocene (p. 41). It is not known on what basis Arnold assigned an Oligocene age to the Allenby; presumably he followed the dating of Rice (1947) and Shaw (1952).

Russell (1958, p. 86) suggested that the conflicting age assignments could be reconciled if an unconformity were assumed to be present within the Allenby Formation, separating middle Eocene from late Oligocene strata. Rouse and Mathews (1961,

pp. 1079-1080) obtained a potassium-argon radiometric date of 48 m.y. (middle Eocene) from biotite within a volcanic ash bed lying stratigraphically 100 to 120 feet below the mammal horizon. The potassium-argon date thus confirms the age assignment of the mammal remains, but does not rule out the possibility of an unconformity above the mammal horizon. Hills (in press) undertook a provenance study of the sediments, and concluded that the single paleocurrent direction and source of the Allenby Formation made the presence of an unconformity unlikely. The present study indicates that although there are floral changes from bottom to top of the section, there is no evidence of any sudden floral change which would indicate the presence of an unconformity.

There is a close resemblance in the plant microfossil assemblage from the Allenby Formation and that described by Wodehouse (1933) from the Green River Formation. This correlation will be dealt with in detail under the section on correlation.

Because the age of the Allenby Formation is based on the presence of mammals that are also present in the well-known Green River Formation, the age and correlation of the Green River will be reviewed.

Age of the Green River Formation

The most recent dating of the Green River Formation is middle Eocene (Bradley, 1964, p. A28). In part this dating is based on fossil mammal remains found within shoreline facies of the Green River, and in part on intertonguing relationships with the Wasatch and Bridger Formations which are also dated by mammal remains. The Green River Formation of Wyoming is correlated with continental European Eocene on the basis of mammals.

The following is a summary of the pertinent literature on the age and correlation of Wasatch, Green River and Bridger Formations. The stratigraphic relationships of these three formations is given in Fig. , modified after Bradley, 1964, p. A18.

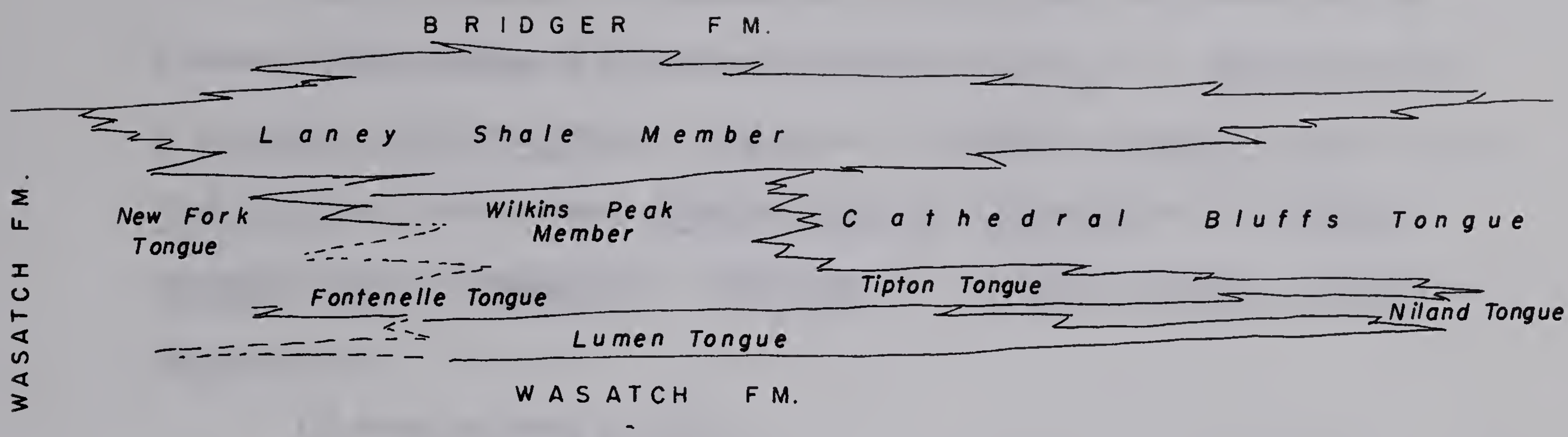


Figure 8. Diagramatic section indicating the relationships of the Wasatch Formation, Green River Formation and the Bridger Formation. The Green River Formation is composed of the Lumen Tongue, Fontenelle Tongue, Tipton Tongue, Wilkins Peak Member and the Laney Shale Member. (Modified after Bradley, 1964, p. A18).

McGrew and Berman (1955, p. 110) reported finding abundant crocodile, turtle, garpike and the small fish Knightia in the Laney Shale (formerly Morrow Creek) Member in Tps. 26 and 27 R 105 W, Wyoming. McGrew (1959, p. 125) reported finding the following fossil mammals from the Laney Shale member: Leptotomus parvus McGrew, Diacodon edenensis McGrew, Notharctus gracilis Marsh, Omomys carteri Leidy, Shoshonius? laurae McGrew, Paramys delicatus Leidy, Thisbemys sp., Scuiravus nitidus Marsh, Hyrachyus sp., Hyopsodus lepidus Matthew, Melanosaurus sp. Of these, Hyopsodus lepidus appears to be diagnostic of late Bridgerian, whereas Leptotomus parvus is known only from the lower Bridger. Thisbemys sp. approaches most closely species from the lower Bridger.

McGrew and Roehler (1960, p. 157) report the presence of the following fossil mammals in the Laney Shale Member: Hyopsodus lepidus, Nyctitherium Notharctus, Hyrachyus, Mysops parvus?, Tillomys, Paramys, Taxymys lucaris. Of these, they state (p. 157): "Most of these forms occur through the Bridger except Hyopsodus lepidus which seems to be diagnostic of Twin Butte or late Bridgerian". Thus it appears that the upper time limit of the Green River Formation is late Bridgerian, considered to range from middle Eocene to late Eocene (?).

Morris (1955, p. 197) reported the following fossil vertebrates from the Cathedral Bluffs Member of the Wasatch Formation (see Fig. 8): *Periantherium* cf. *P. marsupium*, *Nyctitherium* sp., *Trogosus* cf. *T. latidens*, *Absarokius witteri* n. sp., *Notharctus* sp., Ishyromyidae, *Viverravus gracilis*, *Didymictus* cf. *D. altidens*, *Hyopsodus paulus*, *Orohippus* sp., *Eotitanops* sp., *Hyrachyus modestus*, *Microsus* sp., *Sarcolemu* sp.

Of these he states (p. 197):

"*Trogosus* cf. *T. latidens* together with such other adequately known genera and species as *Viverravus gracilis*, *Hyopsodus paulus*, *Orohippus*, *Microsus* and *Sarcolemur* date the Cathedral Bluffs fauna as Bridgerian .... The genus *Absarokius* .... has been found only in the Lysite and Lost Cabin faunal zones and despite the rarity of the genus, it may have some bearing on the correlation of the Cathedral Bluffs member.

"The presence of *Didymictus* cf. *D. altidens* in the Cathedral Bluffs tongue stresses the relationship of the fauna to that of the Lost Cabin zone".

Gazin (1959), p. 135) revised Morris' (1954) list to include the following: *Perantherium*, 2 sp., *Notharctus* sp., *Trogosus*? *latidens* Marsh, *Absarokius witteri* Morris, Pyramyid rodent, *Viverravus* cf. *V. lutosus* Gazin, *Didymictus* cf. *D. altidens* Cope, *Hyopsodus* sp., cf. *Hyracotherium* sp., *Eotitanops* sp., *Hyrachyus* cf. *H. modestus* Leidy, cf. *Hexacodus* sp.

McGrew and Roehler (1960, p. 158) reported finding a single tooth of *Sciuravus nitidus* in the Cathedral Bluffs Tongue. This rodent is considered to be of Bridgerian age. A second rodent fauna suggested an age intermediate between the Lostcabinian and Bridgerian.

Gazin (1952, p. 13) suggested that the fossil vertebrates of the New Fork Tongue of the Wasatch Formation represent the upper stage of the Lost Cabin age. The fauna of this tongue is as follows: *Meniscotherium chamense* Cope, *Hyrachyus* spp., *Bathyopsis*, *Lambdotherium popoagicum* Cope, *Hiptodon*, *Esthonyx*, *Ambloctonus* cf. *A. major* Denison.

Morris (1954, p. 199) suggested that the New Fork Tongue of the Wasatch Formation may correlate in part with the Tipton Tongue of the Green River Formation.

The fauna of these two tongues of the Wasatch serve to date the Wilkins Peak Member and the base of the Laney Member of the Green River Formation as Lostcabinian (upper Wasatch).

McGrew and Roehler (1960, p. 158) reported the following fauna from the Tipton Tongue of the Green River: Cynodontomys, Hyracotherium, Lambdotherium. This fauna indicates a Lostcabinian age for this unit.

McGrew and Roehler (1960, p. 157) state that in 1952 R. W. Brown found a number of vertebrate sites in the Wasatch Formation. From these collections Gazin identified Meniscotherium robustum. Later Roehler obtained specimens of the following: Esthonyx bisulcatus, Haplomylus cf. speririanus, Meniscotherium cf. priscum, Hyracotherium. These fossils indicate that the lower 930 feet of the Wasatch is Greybullian. Above the Greybull sequence, collections included: Cynodontomys cf. latidens, Hyopsodus cf. powellianus, Hyopsodus cf. metalis, Hyracotherium. They state (p. 157):

"The range in size of the Hyopsodus material at this locality is suggestive of Lysitean (Gazin, personal communication). Fossil data indicate lower parts of the Lumen tongue in the little mountain area are Greybullian and Lysitean".

Thus the evidence of fossil vertebrates indicates that the age of Green River Formation ranges from Greybullian (Luman Tongue) to Bridgerian (Laney Shale Member).

Of the genera listed above, Esthonyx, Viverravus and Hyracotherium are common to the Tertiary of both Europe and North America. Esthonyx and Viverravus are correlative at the generic level, whereas early species of Hyracotherium are common to both continents.

In North America the base of the Eocene is placed at the first appearance of Hyrachotherium (Eohippus). Simpson (1933, p. 84) states of this:

"Drawing the line (Paleocene-Eocene: present writer's insert) at the first appearance of 'Eohippus' (Hyracotherium) seems to be the most logical and convenient procedure. In Europe this would place the Sparnacian (often included there in the Paleocene) in the Eocene, and in North America would place the Clark Fork (often included here in the Eocene) in the Paleocene".

The term Paleocene was first introduced by Schimper (1874, p. 680-682) for

plant bearing beds at Sezanne and Soissons, France. Gignoux (1955, p. 472) includes these strata within the Lower Eocene. Matthew (1920) states:

"The term Paleocene has been revived by several vertebrate paleontologists in recent years to cover the faunal zones previously known as Basal Eocene. Upon evidence of the vertebrate faunas it is entitled to rank as a distinct epoch, co-ordinate with the Eocene and Oligocene. It includes the Puerco, Torrejon, Fort Union, and probably certain less known vertebrate faunas in this country, and the Cernaysian in France. Its upper limit is marked by the first appearance of the principal modern orders of mammals and of certain modern groups of reptiles simultaneously in Western America and in Western Europe. The lower limit is more doubtfully fixed by the first appearance of placental mammals. The evidence of marine invertebrates and of plants does not at present appear to support the distinction of the Paleocene as a separate epoch. It is possible, however, that it covers the gap between the Cretaceous and Tertiary insisted upon by many stratigraphers and paleobotanists, and there are other possible interpretations that might reconcile the evidence. The writer believes that the epoch may also prove to include the Lance and certain other dinosaur-bearing formations, and that it may belong rather to the Cretaceous than to the Tertiary period. No final conclusions are in order until the evidence in different fields has been satisfactorily reconciled".

Therefore, the Paleocene of North America includes strata considered to be of Tertiary age, predating the first appearance of Hyracotherium. This would include the Montian and Thanetian stages of Europe.

The presence of at least ten genera in common permits correlation of early Eocene strata between North America and Europe. Of these genera, Hyracotherium can be correlated at the species level. Later Eocene deposits show no affinities and boundaries are based on local sequences rather than on correlation on an intercontinental basis.

CHAPTER FOUR

STRATIGRAPHIC PALYNOLOGY

Palynological Correlation within British Columbia

Penhallow (1907) claimed that the Kettle Valley Formation, the Allenby Formation (then referred to as Princeton sediments) and the Coldwater beds at Merritt and Quilchena contained a similar plant macrofossil assemblage, and hence were of the same age. Rice (1947, p. 28) correlated the Allenby Formation with the sediments in the Coalmont Coalfield. Cockfield (1948, p. 33) interpreted the Coldwater beds at Quilchena as being older than rocks of the Kamloops Group, a view also shared by Dawson (1894). Rouse (in Rouse and Mathews, 1961, p. 1079) states that: "from a preliminary study of plant macro-and microfossils ... that the Princeton and Tranquille sediments contain synchronous floras". This flora consists of (p. 1079): "*Equisetum*, *Azolla*, *Metasequoia*, *Sequoia*, *Chamaecyparis*, *Pinus*, *Alnus*, *Corylus* and *Juglans* together with many other species of temperate association".

The present study indicates that the Tranquille sediments are correlative with the early phase of sedimentation in the Princeton coalfield, but that the Coldwater beds at Quilchena, Merritt, and the Nicola-Mamit locality were deposited at the same time as the late phase of sedimentation at Princeton. The sediments at Coalmont are correlative with the entire Allenby Formation at Princeton. The above correlations are based on palynological evidence presented below.

At Princeton and Coalmont three, and possibly a fourth, palynological zones are recognizable.

(1) A basal zone with a dominance of bisaccate forms which constitute 80 percent or more of the total assemblage. *Taxodium* is present but never more than five percent of the total. *Tsuga*, *Carpinus*, *Corylus*, *Betula*, *Alnus* (4 and 5 pored), *Pterocarya* and *Acer* 2 spp. make up the remainder. This is here called the Bisaccate "Zone".

(2) The Bisaccate Zone is overlain by a second zone with an abundance of Azolla which locally is the only microfossil recovered. Throughout the zone Azolla spores constitute 50 percent or more of the total pollen and spores. Bisaccate species occur in about 20 percent. Taxodium shows a marked increase to about 15 percent total pollen. Angiosperms typical of the lowest zone continue to be represented but are never abundant. Anemia poolensis is present but rare. The upper limit of this zone is marked by the Princeton Black Coal seam at Princeton, and by the coal seam exposed at the old mine workings on Collins Gulch at Coalmont. This is designated the Azolla primaeva Zone.

(3) The Azolla Zone is overlain by a third zone which is here called the Pistillipollenites mcgregorii Zone. This is characterized by the presence of Pistillipollenites mcgregorii which is present in all slides studied and constitutes about five percent of the total pollen. Taxodium hiatipites type pollen exceed 50 percent of the total pollen. Metasequoia papillapollenites is abundant in this zone at Coalmont, but is rare at Princeton. Tilia spp., Psilodiporites spp., and Verrucosiporites variabilis first appear in this zone but are rare and therefore not too helpful for correlation. Bisaccate grains constitute less than 15 percent in the basal part of this unit but increase in abundance at the top of the zone. The base of this zone is marked by the coal zone which defines the upper limit of the Azolla primaeva Zone. The top of this zone, at both Princeton and Coalmont, occurs at the base of coarse clastics which form the uppermost sediments in the two basins.

A possible fourth zone, which is at present included in the Pistillipollenites mcgregorii Zone, may prove to be of significance with further work. This zone would include the uppermost strata of the Pistillipollenites Zone, and be defined by the presence of Pistillipollenites mcgregorii, together with the dominance of bisaccate pollen rather than Taxodium hiatipites.

Within the Allenby Formation and the Coalmont sediments the microfloral assemblage changes from a basal bisaccate dominance to a zone dominated by Azolla

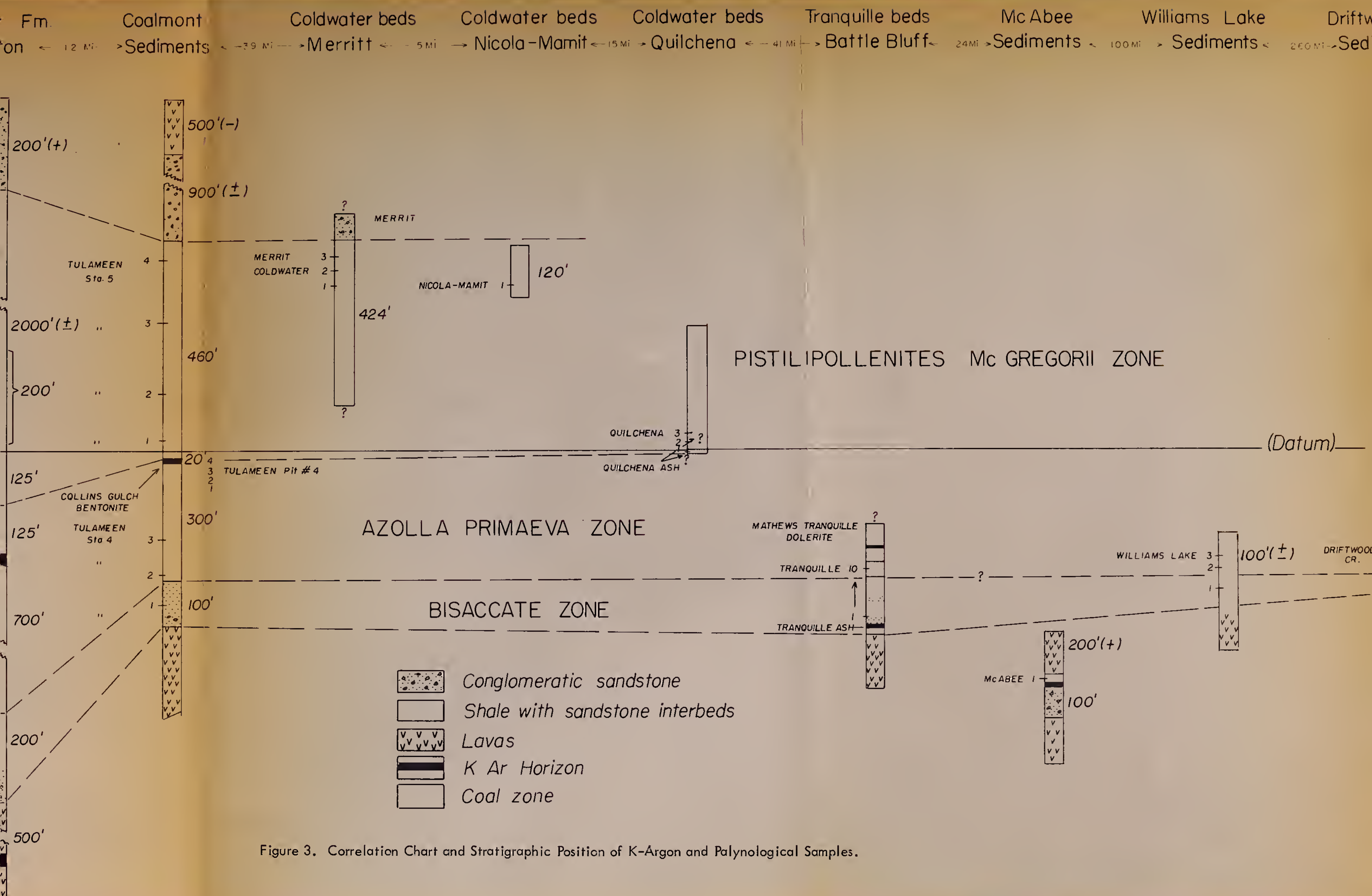


Figure 3. Correlation Chart and Stratigraphic Position of K-Argon and Palynological Samples.

primaeva, which in turn is followed by the Pistillipollenites mcgregorii Zone with a Taxodium hiatipites dominance. At Driftwood Creek, Coalmont and Princeton, Betula claripites is most abundant in the basal sediments, becoming rare higher in the section. At Driftwood Creek, Tsuga viridifluminipites has a similar distribution to Betula, but is rare even in the basal sediments at the other two localities. The presence of either Betula or Tsuga in abundance suggests correlation with the Bisaccate "Zone."

The bisaccate grains range through the entire section, identical species being present from the bottom to the top of the section.

Azolla primaeva and Pistillipollenites mcgregorii have not been found in the same sample in the study area. Rouse (1962) has reported both in samples from Third Beach, but it is uncertain as to whether they occurred in the same sample.

From the stratigraphic relationships determined at Princeton and Coalmont, the other areas of early Tertiary sedimentation throughout the Province may be considered. An abundance of Pistillipollenites mcgregorii in association with Tilia spp. was found at Coal Gully (Merritt Coldwater beds), at the Nicola-Mamit location and at Quilchena. Spores of Azolla primaeva were not found at any of these localities, but fragments of the vegetative part of the plant were found at Quilchena in outcrops stratigraphically below the coal seam which has been mined in the past. This indicates that the exposed sections of the Coldwater beds at Coal Gully, the Nicola-Mamit location and Quilchena are correlative with the Pistillipollenites mcgregorii zone at Princeton and Coalmont, with possibly a few feet of strata at Quilchena equivalent to the Azolla primaeva Zone. A bisaccate dominance in association with Pistillipollenites mcgregorii suggests that the Coldwater beds at Merritt and the Nicola-Mamit location are correlative with the upper part of that zone.

Spores of Azolla primaeva were found in abundance at Williams Lake and at Driftwood Creek, and a single megaspore was found in the upper Tranquille sediments east of Battle Point. The Driftwood Creek and the Williams Lake locality undoubtedly

belong to the Azolla primaeva Zone. The megaspores of Azolla, found in association with an abundance of bisaccate grains, Tsuga viridifluminipites and a low Taxodium count, suggest that the Tranquille sediments are correlative with only the basal Bisaccate "Zone" at Princeton and Coalmont.

At McAbee the spore and pollen assemblage consists of a predominance of bisaccate grains, Tsuga viridifluminipites and Betula claripites. Acer, Pterocarya carpinus, and Carya are also present but rare. This assemblage characterizes the basal sediments at Princeton, Coalmont, Driftwood Creek and the Tranquille sediments at Battle Point, which suggests that the McAbee sediments are correlated with this horizon.

The Princeton Black Coal zone, and the coal seam 400 feet above the base of the sediments on Collins Gulch at Coalmont probably correlate with the section of the Burrard Formation outcropping at Third Beach, Vancouver. The reason for this is that both Azolla primaeva and Pistillipollenites mcgregorii occur in the Burrard, whereas in the Interior localities Azolla occurs below the coal zone and Pistillipollenites above it.

TABLE 2

SPORE AND POLLEN DISTRIBUTION

	Princeton Allenby Form.	Coalmont	Merritt	Quilchena	Nicola Mamit	Tranquille	McAbee	Williams Lake	Driftwood Creek	Green River	Burrard Form.
Pluraecellae sporites A.	x	x	x	x	x	x	x	x	x		
Pluraecellae sporites B.		x		x?							
Phragmosporites quilchenii	x	x	x	x	x				x		
Phragmosporites sp.		x		x							
Diadosporites species		x		x							
Inapertisporites elongatus	x	x	x	x	x	x	x	x	x		x
Osmundasporites cf. elongatus	x	x		x							
Osmundasporites cf. primarius	x	x		x							
Laevigatosporites discordatus	x										x
Laevigatosporites gracilis	x	x		x							x
Laevigatosporites ovatus	x	x	x	x	x	x	x	x	x		
Anemia poolensis	x	x		x							x
Azolla primaeva	x	x		x?		x		x	x		
Deltoidospora ? sp.	x	x									
Verrucosisporites variabilis		x									
Gleichenidites minor				x							
Fern sporangia with annulus?	x			x							
Cycadopites follicularis	x	x	x	x	x	x	x	x	x	x	
Cycadopites sp.		x									
Larix plicatipollenites	x	x	x	x	x	x	x	x	x	x	x
Tsuga viridifluminipites	x	x					x		x	x	x
Picea alipollenites	x	x	x	x	x	x	x	x	x		x
Picea cf. grandivescipites	x	x	x	x	x	x	x	x	x	x	x
Abietineaepollenites sp.	x	x	x	x	x	x	x	x	x		
Alisporties sp.		x									
Pityosporites cf. alatipollenites		x									
Pityosporites elongatus	x	x	x	x	x	x	x	x	x		
Pityosporites magnus	x	x	x	x	x	x	x	x	x		

Table 2 contd.

	Princeton Allenby Form.	Coalmont	Merritt	Quilchena	Nicola Mamit	Tranquille	McAbee	Williams Lake	Driftwood Creek	Green River	Burrard Form.
Pityosporites sp. A		x									
Pityosporites sp. B		x									
Podocarpidites cf. *ornatus*		x									
Podocarpus sp.		x									
Phyllocladites sp.		x									
Taxodium hiatipites	x	x	x	x	x	x	x	x	x	x	x
Metasequoia papillapollenites	x	x	x	x	x	x	x	x	x	x?	x
Cunninghamia concedipites	x	x	x	x	x	x	x	x	x	x	
Taxodiaceaepollenites sp.		x		x							
Betula claripites	x	x	x	x	x	x	x	x	x	x	
Alnus quadrapollenites	x	x	x	x	x	x	x	x	x	x	x
Alnus quinquepollenites	x	x	x	x	x	x	x	x	x	x	x
Carpinus ancipites	x	x	x	x	x	x	x	x	x	x	x
Castanea sp.	x	x	x	x	x						
Juglandspollenites sp.		x									
Carya viridifluminipites	x	x	x	x	x	x	x	x	x	x	
Carya juxtaporipites	x	x	x	x	x	x	x	x	x	x	x
? *Platycarya* sp.		x									
Pterocarya sp.	x	x	x	x	x		x				
Tilia crassipites	x			x						x	
Tilia vesipites	x			x						x	
Tilia tetraforaminipites		x		x						x	x
Salix discoloripites	x	x	x	x	x	x	x	x	x	x	x
Tricolpites scabratus	x	x	x	x	x	x.	x	x	x	x	
Acer quilchensis	x	x		x					x		
Acer tulameenensis	x	x		x					x		
Aesculus ? sp.	x	x	x	x	x	x	x	x	x		
Ericipites sp.	x	x	x	x	x	x	x	x	x		
Momipites coryloides	x	x	x	x	x	x	x	x	x		

Table 2 contd.

	Princeton Allenby Form.	Coalmont	Merritt	Quilchena	Nicola Mamit	Tranquille	McAbee	Williams Lake	Driftwood Creek	Green River	Burrard Form.
Myriophyllum ambiquipites				x							
Pistillipollenites mcgregorii	x	x	x	x	x					x?	x
Potamogeton hollickipites	x	x	x	x	x	x	x	x	x	x	
Sabal granopollenites	x	x	x	x	x	x	x	x	x		x
Psilodiporites krempii	x	x									
Psilodiporites sp.	x	x									
Triporopollenites sp.	x	x	x	x	x	x	x	x	x		x
Triporopollenites cf. *formosus*		x									
Tricolporopollenites sp.		x									
Polycolpites sp.	x	x									
Incertae Sedis Gymnosperm		x									
Pediastrum	x	x		x							
Liquidambar sp.	x			x					x		
Sphagnum 2 sp.	x										
Unidentified fungi	x			x							
W 29	x	x		x							x
Botrychium (?) sp.	x										
Sparganium sp.	x										
Inaperturopollenites sp.	x	x	x	x	x	x	x	x	x		x

Palynological correlation with the Green River Formation

Wodehouse (1933) identified and described the following plant microfossils from the Parachute Creek Member of the Green River Formation of Wyoming:

Gymnospermae

Pinus strobipites

Pinus scopulipites

Pinus tuberculipites

*Picea grandivescipites

Abies concoloripites*

Cedripites eocenicus

*Tsuga viridifluminipites

Abietipites antiquus

*Taxodium hiatipites

Glyptostrobus vacuipites

Cunninghamia concedipites

Ephedra eocenipites

*Potamogeton hollickipites

Arecipites punctatus

Arecipites rugosus

Peltandripites davisii

Smilacipites molloides

Smilacipites herbacoides

Smilacipites echinatus

Liriodendron psilopites*

*Carya viridifluminipites

*Carya juxtaporipites

Juglans nigripites*

Engelhardtia corylipites

Myricipites dubius

*Salix discoloripites

*Alnus speciipites

*Betula claripites

*Carpinus ancipites

*Momipites coryloides

Ailanthipites berryi

Rhoipites bradleyi

Talisiipites fischeri

Vitipites dubius

*Tilia crassipites

*Tilia vescipites

*Tilia tetraforaminipites

*Myriophyllum ambiguipites

Ericipites lonyisulcatus

Ericipites brevisulcatus*

Caprifoliipites viridifluminis

The following plant microfossils have been identified from the Luman Tongue of the Green River Formation by E. Leopold (In Bradley, 1965, p. A30):

cf. Pinus

cf. Cycas

Ephedra cf. torreyana S. Watson

Cunninghamia or Sequoia

Dicotyledons:

Betulaeae

Platycarya*

cf. Engelhardtia

*Pterocarya

Juglandaceae

Zelkova

cf. Morus

Ulmaceae

*Carya

*Tilia

cf. Galium

Monocotyledons:

Nymphaeceae

*Potomogeton

Gramineae

Spores

* cf. Schizaceae

Algae

* Pediastrum

Chrysophyta

* Those preceded by an asterisk have been identified from the Allenby Formation or related strata in British Columbia.

The above floral lists indicate that the early Tertiary strata in British Columbia

have 17 species in common with the Green River Formation, and six similar forms. Thus there is a much better correlation than previously thought. About 35 percent of the species in the Allenby Formation are present in the Green River. Rouse and Mathews (1961, p. 1080) state of the correlation with the Green River Formation:

> "In terms of age, the Princeton and Tranquille floras are synchronous with that from the Green River formation of Wyoming and Colorado. However, there appears to be a fairly large discrepancy in the floral composition between the two. This is not surprising, inasmuch as there are some 4 1/2° of latitude between the two, together with unknown ecological and physiographical differences. The discrepancies in floras point out the continuing need for fundamental research on the extent of the effect which latitude, altitude, mountain barriers, climate, and other factors had on synchronous but geographically isolated floras of the Tertiary".

I am in agreement with the general conclusion that latitude and altitude etc. influence the number of species in common, but would like to point out that with additional work more genera and species will undoubtedly be discovered which will further indicate affinities with the Green River Formation.

CHAPTER FIVE

PALEOECOLOGY AND PALEOCLIMATE

Paleoecology

Paleoecological interpretations using pollen and spores are based in part on unknown: for example, dispersal distance; mechanism of dispersal; wind versus insect transport; differential pollen production; differential preservation; distance of plant from site of deposition; and uncertainty of affinities with modern genera. In spite of these limitations valid inferences can be made.

Table 3 summarizes the habitat and climatic requirements of extant genera which have been identified. Only a few representatives of the entire assemblage are referred to in the following discussion.

The sediments themselves yield information about the environment of deposition, and when combined with the palynological observations, show the flux of paleoenvironments.

The basal sediments at all localities are coarse angular sedimentary breccias derived from the underlying bedrock, possibly representing slightly reworked talus, and implying little stream action. These basal sediments are overlain by lithic sandstones of local origin and grade upwards into laminated shales and silty shales with lenses of sandstone. The standstone lenses may be interpreted as the bedload of a river, whereas the shales and silty shales represent the back-swamp deposits. These latter deposits are overlain by extensive coal seams which indicate swamp with lush vegetation. The coal sequence is overlain by shales, silty shales and minor amounts of coal and an increasing number of sandstone lenses, terminated by an influx of coarse clastics, which indicates a return to the river valley system with well defined back-swamp deposits and the eventual dominance of the river system.

The composition of the upper sandstones and coarse clastics is arkosic with

TABLE 3

HABITAT, DISTRIBUTION AND CLIMATIC TOLERANCE OF MODERN GENERA WHICH HAVE BEEN IDENTIFIED DURING THE COURSE OF THIS STUDY (MODIFIED AFTER ROUSE, 1962)

GENUS	HABITAT	CLIMATE
Sphagnum (Sphagnumsporites)	moist areas, bogs, acid moors, pond margins; cosmopolitan	
Anemia	wet lowlands and rain forests, particularly tropical America	subtropical to tropical
Osmunda (Osmundasporites)	O. regalis low woods, peaty thickets, swales; O. claytoniana moist woods and thickets; mainly Northern Hemisphere	tropical to cool temperate
Azolla	quiet water of lakes, ponds, etc.	tropical to warm temperate
Pinus (Pityosporites)	swamp to mountainous, rocky, Northern Hemisphere	cold to cool temperate, variable
Picea	P. glauca woods in good soils, dwarfed in dry areas	cold to cool temperate
Abies	woodlands to mountainous	cold and cool temperate
Larix	swamp to uplands, Northern Hemisphere	cold to cool temperate
Tsuga	T. canadensis upland; T. caroliniana hilly or rocky woods; T. heterophylla mountainous moist; Asia, from Himalayas to Japan, North America	
Podocarpus (Podocarpidites)	moist woodlands, mostly mountains of Southern Hemisphere, Caribean, S. America	subtropical to tropical

Table 3 contd.

GENUS	HABITAT	CLIMATE
Taxodium	swamps and floodplains southeastern United States and Mexico	subtropical
Metasequoia	wet ravines in mountains, Hupeh Province, China	
Betula	B. lenta and B. lutea upland and deep woodland; B. nigra bottomland and border of stream; B. pumila bog and wooded swamp, Northern Hemisphere	cool to cold temperate
Alnus	swamp, wet woods, stream margin, cosmopolitan	variable
Carpinus	C. caroliniana woods and swamps, coastal to upland	cool temperate
Castanea	C. dentata dry gravelly or rocky soil; C. pumila dry woods and thickets	warm to cool temperate
Juglans	woods and river terraces, S.E. United States	subtropical to warm temperate
Carya	C. aquatica bottomland and swamp areas, often inundated coastal plain; C. tomentosa dry to moist woodland; China Indo-China, Eastern North America	subtropical to cool temperate
Tilia	woodlands, Northern Hemisphere	temperate
Salix	damp thickets, swamp, cool woods, cosmopolitan	variable
Acer		warm to cool temperate
Aesculus	woods, bottomlands and stream borders and thickets	

Table 3 contd.

GENUS	HABITAT	CLIMATE
Myriophyllum	lakes, ponds, streams	subtropical to cool temperate
Potamogeton	herbaceous stream and pond, a few sea margin	subtropical to cool temperate
Sabal	lowlands, river bottoms and coastal plains; southeastern United States, Caribbean, Colombia	tropical to subtropical
Sparganium	S. eurycarpum shallow water chiefly argillaceous soils; S. androcladum muddy or peaty shores, swamps, shallow water	cool temperate
Chamaecyparis	swamp moist	subtropical to cool temperate
Thuya	high summits Northern Hemisphere	cool to cold temperate
Equisetum	pond and stream borders	temperate
Cercidiphyllum	wet stream valleys, Hupeh Province, China	subtropical

little detritus from other sources. Thus we can infer that the uplands were granitic bodies whereas the lowlands were such rock types as the Nicola Group volcanics.

Plant microfossils indicate a similar sequence of environments. The significance of the basal Bisaccate "Zone" is uncertain but may be related to the volcanic activity which preceded the deposition of sediments. This floral zone corresponds to the coarse basal clastics.

The Bisaccate "Zone" is overlain by the Azolla primaeva Zone, which is composed of a dominant Azolla microflora with secondary dominants of bisaccate forms and Taxodium.

Both macrofossils and the microfossils of Azolla primaeva are found in this zone. This association of the macro and microfossils, and also the fact that the massulae and megaspores are shed directly into the water, indicate that this plant grew in-situ. Thus we can infer quiet water pond or lake deposition. Taxodium, which increases in abundance upwards in this zone, is a moist swamp or stream border tree. It is, however, wind-pollinated and there is always the possibility that the tree grew elsewhere. Pollen of this genus occurs frequently in clusters in sample preparations, suggesting that complete microsporangia have been macerated. This would imply that Taxodium grew at the site of deposition. Spores of Osmunda, Anemia and the Polypodiaceae also indicate a moist environment. This zone corresponds to the lower shale unit.

The microfloral assemblage of the coal seams is little known because better preparations could be made from the overlying and underlying shales. A single coal sample from the Princeton Black Coal seam exposures on the east side of the Similkameen River at Princeton was macerated. The total spore and pollen assemblage consisted of small (20 to 40 micron), inaperturate, smooth to scabrate spores, many of which were ruptured in the typical manner of Taxodium. This suggests that the coal is largely derived from Taxodium or related forms.

The shales, silty shales and coal overlying the lower-most mined coal seams at

Princeton and Coalmont are characterized by Pistillipollenites mcgregorii, the zone index, Taxodium and bisaccate grains. Taxodium is dominant in the lower part of this zone, whereas the bisaccates become progressively more abundant and are the dominant form in the upper part of the section. Pistillipollenites mcgregorii is not ecologically diagnostic, however, the extreme abundance of Taxodium (often exceeding 80 percent total spores and pollen) indicates standing or slowly moving bodies of water. The increase in bisaccate grains corresponds in position to the increase in number of coarse clastic lenses. This suggests that there was a gradual increase in stream activity which made the environment less and less suitable for Taxodium, which gave way to coniferous forests bordering fast moving streams.

The upper coarse, cross-stratified clastics are indicative of the stream environment, and to date no shales suitable for palynological study have been recovered.

The entire sequence of events described in the preceding paragraphs is fully developed at Princeton and Coalmont only. The Coldwater beds at Merritt, on the Nicola-Mamit Road, and at Quilchena represent only the closing phase of sedimentation with increasing stream activity. The Tranquille beds, McAbee sediments, Williams Lake sediments and Driftwood Creek sediments represent only the early phase in which streams were not a dominating factor, and the area was characterized by numerous ponds. The culmination of this early phase in coal development is not represented at any of the latter four localities.

Paleoclimate

A study of Table 3 indicates that the microfossils recovered during this study suggest either a subtropical or a cool to cold temperate climate. This seeming disagreement can be explained on the basis of the ecological requirements of the plants. From the study of the coarse sediments we can infer uplands of granitic rocks surrounded by areas of low relief. It is therefore possible that the lowland vegetation was subtropical and

that those genera indicative of cooler climates grew at a higher elevation at some distance from the site of deposition.

Rouse (1962, p. 193) states:

"The eight genera inhabiting essentially subtropical regions are: Anemia, Lygodium, Podocarpus, Taxodium, Sabal, Cannophyllites (cf. Canna), Ficus, and Pistillipollenites (cf. Rusbyanthus). The remaining twenty-eight genera with modern affinities are temperate in range with a decided leaning toward cool temperate.

"The obvious conclusion is that, although the Burrard flora represents a warmer environment than the one presently existing at Vancouver, conditions were not tropical or subtropical".

I would interpret the evidence to date to indicate a subtropical bordering on warm temperate lowlands, with the cool to cold temperate aspects being contributed from elevated areas surrounding the basins of deposition. The composition of the sediments in the interior basins indicates that eroding granitic bodies stood much higher than the surrounding country rocks.

CHAPTER SIX

PALYNOLOGICAL SAMPLE PREPARATION, MOUNTING, CODING AND SYSTEMATICS

Sample Preparation

The success or failure of a palynological study depends on a thorough knowledge and application of techniques. Mediocre preparations result in loss of spores and pollen or gives material unsuitable for study. Therefore, it is essential that one familiarize himself with all literature available on sample preparation prior to commencing a palynological study. The reader is referred to the following articles which deal primarily with sample preparations and mounting: Arms, 1960; Brown, 1960; Erdtman, 1943; Funkhauser and Evitt, 1959; Holst, 1954; Jeffords and Jones, 1959; Kuyl, 1961; Lee, 1964; Raistrick and Simpson, 1933; Raistrick, 1934, 1937; Staplin et al, 1960; Tschudy, 1958, 1960; Wilson, 1946, 1959; and Wodehouse, 1933. Brown's (1960) paper is a collection of techniques employed in palynological laboratories throughout North America and Europe.

Samples used in this study ranged from lignite through coaly shales to shale and siltstone. All lignite samples contained 5 to 10 percent inorganic matter, and therefore required treatment with hydrofluoric (HF) acid.

The general procedure used for microfossil preparation is outlined in Fig. 11. This treatment was adhered to in all samples except the silty lignites. It was found that a more complete removal of inorganic material resulted if excess organic material was removed prior to treatment with HF acid.

The hydrofluoric acid treatment was carried out in polyethylene beakers placed in a fume hood.

Singh (1963, p. 95) states that samples should never be left in potassium carbonate for periods longer than five minutes. Several samples which required oxidation

Sample

Crush to 1/8 inch or less

Wash in distilled water

10% cold HCl acid for 30 min. to remove carbonates

Wash at least three times in distilled water

52% cold HF acid, 5 times volume of sediment, allow to stand for 12 hr., to remove silicates and silica

Wash 3 times in distilled water

residue dark brown or black unoxidized organic residue

oxidize with cold 70% HNO_3, or (600 cc 70% HNO_3 plus 30 gm $KClO_3$) Schultze sol'n for 10-15 min.

Use 5% K_2CO_3 or 5% KOH to remove humic acid. Boil 10-15 min. if necessary.

Wash in distilled H_2O and differentially centrifuge

mount residue

yellow or yellow brown

add 5% K_2CO_3 or 5% KOH to remove humic acid. Boiling for 10-15 mins. improves results.

mount residue

Figure 9. Flow Sheet for Microfossil Preparation.

but which were almost barren after treatment with nitric acid for ten minutes yielded excellent microfossils after treatment in cold potassium carbonate for periods of 12 to 36 hours. One sample yielded excellent results after four hours in boiling potassium carbonate. The treatment given any one sample should be adapted to the sample and not to treatment given another.

Centrifuging was carried out in an International Centrifuge, Universal Model UV. Differential centrifuging was accomplished by starting centrifuging at 2200 rpm. for three minutes and progressively decreasing the rpm. and time until small spores or pollen appeared in the wash. Fifteen to twenty washes were sometimes required to properly clean a sample.

All samples were stained with Safranin Y dissolved in distilled water prior to mounting. This was carried out by adding a drop of stain directly to a small amount of organic residue on the coverslip or on the slide.

Samples from Driftwood Creek, Quilchena, Merritt, Nicola-Mamit Road, and some samples from Coalmont were mounted in corn syrup with added phenol crystals following the technique outlined by Radforth and Rouse (1954, p. 189). This mounting media has the following advantages: spores and pollen grains can be rotated at any time, and the index of refraction permits a satisfactory contrast between sporomorph wall and mounting media. It has the following disadvantages: never hardens and under humid conditions will flow, must be stored horizontally, may become infected with fungi if a sufficient amount of phenol crystals is not added, and may develop fractures if air is dry.

Mounting

The laboratory supply of corn syrup became infected with fungi, therefore it was decided that a different media should be used on the remaining samples. Elvanol (polyvinyl alcohol) suggested by Funkhauser and Evitt (1959) was adopted and found to

be a highly satisfactory mounting media. Aroclor was used to cement the coverslip to the microscope slide.

Depending on the spore and pollen concentration, from five to ten microfossil slides were prepared from each sample. In clean slides with an abundance of spores and pollen, five slides were prepared, whereas ten were prepared in poorer samples.

The microfossil slides are stored in a Can. Lab. Slide Cabinet, with 25 horizontal trays. Each tray holds 20 (75 mm x 25 mm) microscope slides. The trays are numbered 1 to 25 from the top down. Individual slide positions on each tray are numbered 1 to 20 starting with position 1 in the lower left and proceeding to position 10 in the upper left. Position 11 is in the lower right, and position 20 is in the upper right.

Each microfossil slide bears the following information: sample no., cabinet no., tray no., position no., and slide no. Each prepared slide was assigned a number 1 to 5 or 1 to 10 in order to differentiate slides of the same sample. This is referred to as the slide number.

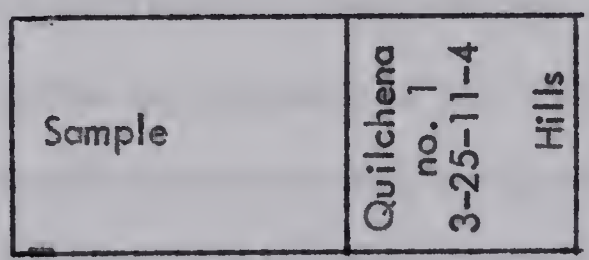


Figure 10. Coding on microfossil slide.

For example, sample Quilchena No. 1, 3-25-11-4 decoded gives sample no. (Quilchena No. 1), cabinet no. (3), tray no. (25), position no. (11), slide no. (4). (See Fig. 12).

Each illustrated specimen or type described in the text is followed by the above information plus microscope co-ordinates. The co-ordinates so listed all refer to the Lietz microscope with camera attachment. The slides are always inserted onto the microscope stage with the label on the right.

Illustrations

Adox KB 14 film developed in D72, diluted 2 parts water to one part solution, processed for eight minutes, and Agfa IFF, developed in Rodinol diluted 1:100 in distilled water for 20 minutes were used during this study. Best results were obtained with Agfa IFF, and its use in further studies is recommended.

Kodak F4, F5, and Polycontrast F and Kodak Brauvire paper developed in Dektol developer were used for printing. Either Polycontrast F or the Kodak Brauvire are recommended. Kodak Brauvire appears to give the best results.

Taxonomic Remarks

The problem concerning taxonomy and nomenclature of fossil spores and pollen is an interesting topic and one which all palynologists must appreciate prior to any work. It is, however, unnecessary to give a detailed description of previous classification systems, as this topic has been adequately treated elsewhere (Traverse, 1955), pp. 80-90; Singh, 1963, pp. 78-93). The classification system used here is that proposed by Rouse (1957). Under this system the following categories of plant microfossils are recognized:

(1) When the generic affinities are known, the generic name is used, together with a specific epithet which is composed of a morphologically descriptive root and either of the suffixes - sporites or pollenites. e.g. Gleichenia concavisporites, Metasequoia papillapollenites.

(2) Where the relationship of spores or pollen to a modern family is indicated, the genus of that family to which the particular spore or pollen appears to be most closely related, is used in combination with either of the suffixes - sporites or pollenites, e.g. Hymenophyllumsporites trichoma.

(3) Where no family relationship is known, morphologically descriptive roots in combination with suffixes form the generic epithet, e.g. Pistilli pollenites Mcgregori.

(4) Spores or pollen which are obviously new species of previously described

genera are described and incorporated within that genus, e.g. Deltoidospore rhytisma, a new species of the genus Deltoidospora Miner (1935).

(5) If spores are known to be conspecific with previously described species, then those names are employed.

(6) When two names have been applied to apparently identical microfossils in the same year, the name indicating natural affinities is given in preference to an artificial designation.

Singh (1963, p. 87) has already pointed out that this procedure may be contrary to the rules of priority, and therefore, should be deleted from the system.

Further criticisms have been presented against this system (Potonie, 1958b, p. 494; Pocock, 1964, p.), however, the writer feels that there is justification for the system, with the exception of category 6 which may violate the rule of priority, and will therefore apply it in this study.

Systematics

FUNGI IMPERFECTI

Genus Pluricellaesporites van der Hammen (1954)
emend Clarke 1965

Pluraecellaesporites Sp. B.

1950 Brachysporium (?) bulbosum Wilson and Webster (In Saulner, 1950) Unpubl. M.Sc., Thesis, Univ. of Mass., p. 25, pl. 1, fig. 1.

DIAGNOSIS: Bilateral symmetry; alete; linear; one ranked filaments, length of individuals cells four to five microns, width six to eight microns, wall translucent, 1.5 microns thick, smooth, septations bidentate.

REMARKS: A single specimen identical to the one illustrated by Saulner was found at Coalmont, British Columbia.

AFFINITIES: Fungi Imperfecti.

OCCURRENCE AND ABUNDANCE: Only a single specimen was found at Coalmont, British Columbia.

GEOLOGIC RANGE: Prior to this study, this spore had only been reported from strata of Paleocene age. Correlation of the strata at Coalmont with the Allenby Formation indicates a middle Eocene age for this locality. Known range Paleocene to middle Eocene.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Plate 1, figs. 1 and 2 Slide No. TS5-3-3-16-3-4 Co-ord. 115.6/61
TS5-3-3-16-2-3 115.7/61

Pluraecellaesporites Sp. A.

Plate 1 figures 3 and 4

1946 Brachysporium sp. Wilson and Webster, American Jour. Bot., vol. 33, p. 25, pl. 1, fig. 2.

1950 Brachysporium (?) sp. Saulnier, Unpubl. M.Sc. Thesis, Univ. of Mass., p. 25, pl. 1, fig. 2.

1962 Branchysporium sp. Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, p. 81, pl. 25, figs. 1-2.

1964 cf. Brachysporium sp. Vagvolgyi, Unpubl. M.Sc. Thesis, Univ. of Alberta, pl. 9, fig. 8.

DIAGNOSIS: "Spores composed of one to several cells and range from 30 to 76 microns in length, depending upon the number of cells in the spore. In width the widest cell ranges from 28 to 48 microns. The largest cell, usually the terminal, is darker brown than the others; it is frequently black and opaque. The other cells are usually translucent and brown. The crosswalls are two-lobed, each lobe being triangular in view. The surface of the spore is smooth to slightly roughened", (Wilson and Webster, 1946, p. 271).

REMARKS: Specimens of this type encountered ranged from 31 to 49 microns in length, and 13 to 23 microns in width. Length: maximum width = 2:1 to 2.5:1. In

the specimen illustrated by Wilson and Webster (1946, p. 272, fig. 1) the apex of the triangular cross-walls project towards the base of the spore. The present work indicates that it projects in either direction. The present interpretation is that these triangular cross-walls are the result of compression and not a reflection of the original shape.

OCCURRENCE AND ABUNDANCE: At Princeton 27 spores of this type were encountered in a count of 4400. They occur throughout the entire section. Present in slides from all localities studied.

AFFINITIES: For full discussion, see Wilson and Webster (1946, p. 273). Brachysporium obovatum was described from decaying wood.

GEOLOGIC RANGE: Spores of this type have been reported from the Lower Cretaceous (Vagvolgyi, p. 19, fig. 8); Paleocene (Wilson and Webster, 1946, p. 271). The writer has seen identical spores in the Cenomanian Dunvegan Formation. Although the relationship of this fossil to spores of the extent genus is uncertain (Wilson and Webster, 1946, p. 273), it does indicate that similar forms still exist. Therefore, the present information indicates that this spore has little or no stratigraphic importance.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 1, fig. 3 Slide No. TS5-3-3-16-1-2 Co-ord. 122/40.4

Pluraecellaesporites quilchenii n. sp.

Pl. 1 fig. 5-10

DIAGNOSIS: Conidia (?) light brown elliptical to oblong-elliptical, aniso-polar, inaperturate, three to four septae (generally three). Point of attachment to conidiophore (?) marked by a small protrusion on the smallest pole. Spore size ranges from 21 to 34 microns in length by 8 to 13 microns in width. The length: width ratio is 2:1 to 3:1. Individual cells range from five to eight microns in length. Exine smooth and less than one micron in thickness.

AFFINITIES: The spores are very similar to some of the phragmosporous fungi,

for example Helminthosporium sp.

OCCURRENCE AND ABUNDANCE: This species was not encountered in formal counts, but did occur frequently in slides from Quilchena.

GEOLOGIC RANGE: The strata at Quilchena are correlated with the Allenby Formation, of middle Eocene age. Although reported only to date from the Eocene, the assignment of stratigraphic range of this species will have to await further reports from independently dated horizons.

(a) TYPE LOCALITY: Coldwater Beds, Quilchena, B.C.

HOLOTYPE: Pl. 1, fig. 5-8.

(b) REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 1, figs. 6-8	Slide No. Q-3-3-23-12-6	Co-ord. 112.9/65.3
Pl. 1, fig. 5	Slide No. Q-3-3-23-12-6	Co-ord. 113.4/65.3
Pl. 1, figs. 9 & 10	Slide No. Q-3-3-23-12-6	Co-ord. 108.2/69.4

Pluraecellaesporites sp.

Pl. 1, fig. 11-13

DIAGNOSIS: This species is almost identical to P. quilchenii except that it is much larger. Size range, length 57 to 73 microns, width 26 to 29 microns; length to width ratio, 2:1 to 2.5:1.

AFFINITIES: Imperfect Fungi. See discussion following P. quilchenii.

OCCURRENCE AND ABUNDANCE: Rare. Only two specimens of this type were encountered at Quilchena, B.C.

GEOLOGIC RANGE: Total stratigraphic range for this spore is unknown. It resembles Clasterosporites sp. Pastiels (1948, p. 54)

Dyadosporites van der Hammen (1954) emend. Clarke 1965.

Dyadosporites sp.

Pl. 1, fig. 14

DIAGNOSIS: Spore two celled, oval-ovate to obovate, distinctly anisopolar,

inaperturate. Apical cell larger than basal cell. Basal cell has a distinct hilum marking point of attachment to conidiophore. Exine levigate, and less than one micron thick. Length about 23 microns; width about 13 microns.

AFFINITIES: Fungi Imperfect.

OCCURRENCE AND ABUNDANCE: Rare, Coalmont Coalfield and strata at Quilchena.

GEOLOGIC RANGE: Known range middle Eocene.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 1, fig. 14 Slide No. TS5-3-16-2-3 Co-ord. 114/56

Incertae Sedis

Genus: Inapertisporites van der Hammen ex Rouse, 1959.

Inapertisporites elongatus, Rouse 1962.

Pl. 1, fig. 17 & 18

DIAGNOSIS: "Spore small, elongate elliptical in outline, with a thick wall (ca. 3μ). The spores are a deep melanin brown in color, and have at least one very small pit on the wall; this is sometimes central and sometimes terminal. Size range 6 to 15 microns" (Rouse, 1952, p. 208, pl. 5, figs. 14-15).

REMARKS: Identical spores were encountered in all samples studied. There is some overlap of characteristics of Monoporisporites and Inapertisporites. The former is characterized by a distinct pore or hilum, whereas the latter lacks either pores or a hilum but may have irregular pits which may be mistaken for pores.

AFFINITIES: Probably fungal in origin.

OCCURRENCE AND ABUNDANCE: Present in all samples studied, but never very abundant.

GEOLOGIC RANGE: Because of the tendency to ignore fungal spores in palynological studies, it is difficult at the present time to assess their stratigraphic value.

At Princeton, British Columbia, spores of this type are associated with mammal remains, indicative of a middle Eocene age. Potassium argon dates have also indicated a middle Eocene age.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 1, figs. 17-18	Slide No. Q3-3-23-12-6	Co-ord. 109.6/66.5
	Q3-3-23-12-6	108.2/69.5

DIVISION PTERIDOPHYTA

CLASS FILICOPSIDA

ORDER FILICALES

FAMILY OSMUNDACEAE

Genus Osmundacidites Couper 1953

Osmundacidites cf. elongatus Rouse 1957 N. Comb.

Pl. 2, fig. 1-3

1957 Osmundasporites elongatus Rouse, Can. Jour. Bot., vol. 35, p. 362, pl. 3, fig. 59-60.

1962 Osmundasporites sp. Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, p. 86, pl. 25, fig. 13-15.

DIAGNOSIS: Trilete; equatorial outline round or fusiform if folded, laesurae simple slits, indistinct, extend to about three fourths the radius of the spore; both surfaces papillate, exine about 1.5 microns thick; papillae up to three microns in length, about two microns wide and with polygonal bases. Size range 58 to 83 microns.

REMARKS: This spore is probably conspecific with Osmundasporites elongatus Rouse.

AFFINITIES: Probably Osmunda. Baculatisporites gemmatus Krutzsch and B. cf. gemmatus Manum are very similar, possibly identical to the above species.

OCCURRENCE AND ABUNDANCE: Fourteen spores of this type were observed. Eleven were encountered in a total count of 4400 grains from Princeton and Coalmont.

GEOLOGIC RANGE: Upper Cretaceous to middle Eocene.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 2, figs. 1-3 Slide No.

Osmundacidites cf. *primarius* Wolff 1935 N. comb.

Pl. 2, figs. 4-6

1935 *Osmundasporites primarius* Wolff, Arb. Inst. Palaobot. u. Petrog. Brennsteine, 5, Preuss, Geol. L.A., Berlin.

1962 *Osmundacidites* sp. Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, p. 86, pl. 25, fig. 16.

DIAGNOSIS: Trilete; round to oval (result of folding); laesurae extend almost to the equator, simple or bordered by a narrow margo; exine about one micron thick; both surfaces ornamented with stout baculae about three microns long by 1.5 microns in diameter, circular to irregular polygonal in cross section; size 40 to 44 microns.

REMARKS: The spore is probably conspecific with *O. primarius* Wolff, but too few specimens were found to permit detailed comparison.

AFFINITIES: Spores of this type correspond very closely to the extant species *Osmunda cinamomea*.

OCCURRENCE AND ABUNDANCE: Only 21 spores of this type were encountered in a total count of 4400 grains from Princeton and Coalmont. They occur sparsely throughout the sections at Princeton and Coalmont but were not encountered elsewhere in this study.

GEOLOGIC RANGE: Wolff described *O. primarius* from Miocene strata of Europe (Wolff, 1962, p. 84), Rouse and Mathews (1962, p. 196) from Eocene of coastal B.C. and Rouse (1964, p. 58) report spores of *Osmunda* sp. from the Miocene and Mio-Pliocene and Graham (1963) respectively.

DIVISION PTERIDOPHYTA

CLASS FILICALES

FAMILY POLYPODIACEAE

Genus *Laevigatosporites* (Ibrahim) Schopf, Wilson and Bentall

Laevigatosporites discordatus Thompson and Pflug 1953

Not illus

1953 *Laevigatosporites discordatus* Thompson and Pflug Palaeontographica, Bd. 94, Abt. B, p. 59, pl. 3, fig. 39-44

1957 *Laevigatosporites discordatus* Rouse, Can. Jour. Bot. vol. 35, p. fig.

1962 *Laevigatosporites discordatus* Rouse, Micropaleo, vol. 8, no. 2, p. 198, fig. 2, fig. 3.

1962 *Laevigatosporites discordatus* Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, p. 88, pl. 25, fig. 21 & 22.

DIAGNOSIS: Size 50 to 90 microns in length. Ellipsoidal in outline. Monolete, short, bi-convex, symmetrical, non-thickened, ends distinctly pointed and often ruptured (after Thompson and Pflug, 1953, p. 59).

REMARKS: Spores are identical to those described by Thompson and Pflug.

AFFINITIES: Polypodiaceae. Rouse (1962, p. 108) states that the closest affiliation appears to be with *Dryopteris*, particularly with *D. latifrons*.

OCCURRENCE AND ABUNDANCE: Recorded in the Allenby Formation at Princeton only. Of a total count of 4400 grains from Princeton and Coalmont, 121 or about three percent belonged to this species.

GEOLOGIC RANGE: Rouse (1957) reports *L. discordatus* from the Oldman Formation. (Upper Campanian) and again from the Burrard Formation (Eocene) of western Canada (1962); Thompson and Pflug (1953, p. 59) report it from Eocene strata and state that it is unknown in younger strata. The mammal remains in the Allenby Formation indicate that it is middle Eocene in age at this locality. Known range - Campanian to Eocene.

Laevigatosporites gracilis Wilson and Webster 1946

Pl. 3, fig. 1

1950 Laevigatosporites gracilis Saulnier, Unpubl. M.Sc. Thesis. Univ. of Mass., p. 29, pl. 1, fig. 7.

1962 Laevigatosporites gracilis Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, p. 88, pl. 25, fig. 23.

DIAGNOSIS: "Spores monolete; narrowly bean shaped; length 27-30 microns, width 16-19 microns; walls smooth, translucent, 1-2 microns thick; monolete suture simple", (Wilson and Webster, 1946, p. 273).

REMARKS: The specimens from British Columbia are considered conspecific with L. gracilis.

AFFINITIES: Of the affinities of this spore (and L. ovatus) Wilson and Webster (p. 273) state: "The inclusion of the above two species of spores in the genus Laevigatosporites is not entirely satisfactory, for there is little doubt that these spores belong to either Thelypteris, Asplenium, Athyrium, Aspidium or Blechnum and probably should have greater phylogenetic recognition than the name implies". This spore is also very similar to spores of the modern genus Acrosticum in shape, size and smooth exine. The name Laevigatosporites may not imply the necessary botanical affinities, but it is decidedly better to use a form-genus in this case rather than arbitrarily assign it to one of the above mentioned extant genera."

OCCURRENCE AND ABUNDANCE: Spores have been found at Princeton, Coalmont and Quilchena, and occur throughout the section.

GEOLOGIC RANGE: A survey of the current literature indicates that this species has been reported from strata of Paleocene to Eocene age.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 3, fig. 1 Slide No. T. Pit 4 #1,3-19-5-3 Co-ord. 117.8/33.6

Laevigatosporites ovatus Wilson and Webster 1946

Pl. 3, fig. 2

1950 Laevigatosporites ovatus Saulnier, Unpubl. M.Sc. Thesis, Univ. of Mass., p. 29, pl. 2, fig. 1.

1957 Laevigatosporites ovatus Rouse, Can. Jour. Bot., vol. 35, no. 3, p. 355, pl. 1, fig. 3.

1962 Laevigatosporites ovatus Pocock, Palaeontographica. Bd. 111, Abt. B, p. 58, pl. 8, figs. 130-132.

1962 Laevigatosporites ovatus Rouse, Micropaleo., vol. 8, no. 2, p. 198, pl. 2, figs. 1-2.

1962 Laevigatosporites ovatus Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, p. 89, pl. 25, fig. 24-25.

1964 Laevigatosporites ovatus Singh, Res. Council of Alberta Bull. 15, p. 99, pl. 13, figs. 9-11.

DIAGNOSIS: Spore monolete; broadly bean-shaped; length 33 to 39 microns, width 22 to 30 microns; wall smooth translucent, 1.5-2.0 microns thick; monolete suture simple.

REMARKS: The specimens from British Columbia are identical to those described by Wilson and Webster. L. ovatus sensu Pocock is more elongate than L. ovatus Wilson and Webster.

Wilson and Webster state their specimens range from 33 to 39 microns in length, whereas Pocock (1962, p. 58) states the length ranges from 39 to 55 microns. The average length of Pocock's species is six microns larger than the maximum dimension of the specimens described by Wilson and Webster. In view of the widely differing ages of the deposits and the difference in size and shape, Pocock's specimen must be referred to a different species. The same argument applies to L. ovatus sensu Singh. Traverse (1955, p. 39, fig. 8, nos. 3-5) illustrates and describes similar forms which he states are

probably polypodiaceous from the Brandon Lignite. These specimens are larger and more elongate than either L. gracilis or L. ovatus and smaller than L. discordatus. L. haardti Potonie and Venetz, as illustrated by Thompson and Pflug, is distinctly more elongate than L. ovatus.

AFFINITIES: See discussion following L. gracillis.

OCCURRENCE AND ABUNDANCE: Sporadic, only 77 were encountered in a count of 4400 grains. Occurs in all strata studied.

GEOLOGIC RANGE: If the specimens described by Pocock (1962) and Singh (1964) are indeed L. ovatus, then the species has little or no stratigraphic value as the range would be Jurassic to Middle Eocene.

It is interesting to note that both writers indicate a Jurassic to Cretaceous range for this species. The type specimen is from the Fort Union Formation of Paleocene Age. If the two reports from the Jurassic and Cretaceous are incorrect, then the true range is from the Upper Cretaceous (Rouse, 1957) to the middle Eocene. The species is never common in the Eocene, and its abundance in the B.C. deposits may be of stratigraphic importance.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 3, fig. 2 Slide No. Q3-3-23-12-6 Co-ord. 115.9/63

FAMILY SCHIZACEAE

Genus Anemia Swartz 1806

Anemia poolensis Chandler 1955

Pl. 3, fig. 3-7

1955 Anemia poolensis Chandler, Brit. Mus. (Nat. Hist.), Bull., Geol., vol. 2, no. 7, pp. 291-314, pls. 32-38.

1962 Anemia poolensis Rouse, Micropaleontology, vol. 8, no. 2, p. 196, pl. 1, fig. 2, pl. 3, fig. 25 & 26.

1962 <u>Anemia poolensis</u> Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, p. 90, pl. 25, fig. 28-32.

1962 <u>Triplanospora</u> sp. Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, p. 124, pl. 30, fig. 44-45.

DIAGNOSIS: Trilete; rounded triangular; radials well rounded; sides convex. Laesurae extending almost to the equator, sinuous, tips often bifurcate. The size ranges from 36 to 60 microns, predominantly 50 to 54 microns. Exine thin, about 1 micron thick and levigate.

AFFINITIES: This spore undoubtedly belongs to <u>Anemia</u> as the original diagnosis was based on spores which were macerated from sporangia.

OCCURRENCE AND ABUNDANCE: Twenty-eight spores of this type were encountered in a total count of 4400 grains from the Allenby Formation at Princeton and Coalmont, British Columbia. Present throughout the section.

GEOLOGIC RANGE: Eocene (Chandler, 1955). Thompson and Pflug, 1953, indicate an Eocene to lower Oligocene age for spores of this type.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 3, figs. 3-7	Slide No. TS5-3-3-16-1-2	Co-ord. 123.3/57.2
		118.2/32.3
	TS5-3-3-16-2-3	114.3/34.2
	TS5-3-3-16-2-3	126.1/60.7
	TS5-3-3-16-3-4	122/57.5

DIVISION PTERIDOPHYTA

CLASS FILICOPSIDA

ORDER SALVINIALES

FAMILY SALVINIACEAE

Genus *Azolla* Lamarck 1783

Azolla primaeva (Penh.) Arnold

Pl. 3, Figs. 8-12, Pl. 4, Figs. 1-4,
Pl. 5, Figs. 1-6, Pl. 6, Fig. 1

1955 *Azolla primaeva* (Penhallow) Arnold, Michigan Univ. Mus. Pal. Contr., vol. 12, no. 4, p. 37-45, 2 pls.

1890 *Azollophyllum primaevum* Penhallow, in Dawson, Roy. Soc. Canada Trans., vol. 8, no. 4, p. 77, text fig. 2.

1934 ? *A. intertrappea* Sahni and Rao, proc. 21st Indian Sc. Cong., p. 26-27.

1962 *A. primaeva* Rouse, Micropaleontology, vol. 8, no. 2, p. 198, pl. 4, fig. 13-14.

1962 *Magnosporites staplinii* Rouse, Micropaleontology, vol. 8, no. 2, p. 210, pl. 5, fig. 23-24.

1962 *A. primaeva* Hills, unpubl. M.Sc. thesis, Univ. of British Columbia, p. 90-91.

1965 *A. primaeva* Hills and Weiner, Micropaleontology, vol. 11, no. 2, pp. 255-261, 2 pl., 1 Fig.

In discussing *A. primaeva*, Arnold (1955, p. 39) states that: "The massulae are round, oval or egg shaped amber colored bodies......260-330 microns in width and 360 to 480 microns in length......the transparent glochidia are at least 40 microns long, although the exact length cannot be determined because of the crumpled condition of the stalks. The stalks appear to be non-septate and of nearly uniform diameter throughout their length. The rounded anchor tips are about 7 microns from one recurved tip to the other......individual microspores are about 20 microns in diameter......spherical with smooth thin translucent walls and triradiate clefts about 4-7 microns long.

"The massulae and megaspore apparatuses are about the same size......the megaspore covered by the perisporic layer is from 250 to 300 microns in diameter;" again, that:

"The wall portion is about 12 microns thick......coarse papillae are present on the surface of some of the specimens".

Hills and Weiner (1965) state that "the massulae range from 96 to 298 microns in width and 144 to 313 microns in length (40 measured). The glochidia are round, non-septate and range from 40 to 96 microns in length and are about 3 microns in width. About 3 to 4 microns below the flukes, the stalk expands slightly and is then abruptly constricted to about one-half to two-thirds its normal diameter.

"The microspores are spherical, trilete, with levigate to faintly granulose thin (Ca. 1 micron) walls. The proximal and distal surface have the same ornamentation. The size ranges from 20 to 35 microns (400 measured) with 23 percent less than 28 microns, 68 percent from 28 to 32 microns and 9 percent from 32 to 35 microns.

"Forty megaspore apparatuses, and megaspore plus perispore fragments were observed. Fine hairlike fibrils about 10 microns in length were observed on one perispore. In several specimens the perispore was broken or partially oxidized and the megaspore exine was clearly visible. The megaspore exine is levigate to faintly granulose, usually folded, and often fragmented...... The total length of the swimming apparatus ranges from 418 to 600 microns with the majority falling into the 529 to 566 micron range. The megaspore exine and covering perispore range from 209 to 369 microns in length and from 221 to 394 microns in width. No floats were observed on any specimens, but the presence of a distinct triradiate mark on the perispore of a single specimen suggests the presence of three floats".

During the course of the present study, a number of anomalous massulae were observed in preparations from Coalmont, British Columbia. Here, instead of having glochidia with well-developed flukes, many of the glochidia lacked tips entirely or

were malformed (pl. 3, figs. 10-11). There is no doubt that these specimens belong to A. primaeva. The phylogenetic significance of this feature will be discussed later.

In addition to observations on the microspores and megaspores, many megafossils were recovered from shales at Princeton, Coalmont, Quilchena, Williams Lake, and Driftwood Creek, British Columbia. Many of these specimens are well preserved and it is now possible to expand the description of the plant itself from careful observation of many specimens.

RHIZOME: Length up to 30 mm. The stem in plan view gives a zig-zag outline, the direction changing at each leaf (sympodial). (Pl. 4, figs. 1 & 3).

LEAVES: Ovate to rounded (Pl. 5, fig. 1) both dorsal and ventral lobe project forward (Pl. 5, fig. 2). Dorsal lobe stiff and with a definite tendency to curve towards the apex. In younger portions of the plant the dorsal leaves overlap but in older portions of the stem they tend to be isolated. Leaf length and width range from 1 to 3 mm, the width generally being slightly less than the length. Leaves on fertile specimens slightly smaller than on vegetative portions.

ROOTS: Solitary, unbranched, 0.5 mm or less in width and up to 50 mm long, tapering slightly towards the root apex (Pl. 5, fig. 2). Relationship of roots to branching is uncertain as specimens with well developed branching seldom had the roots preserved, and vice versa. However, branches arise midway between leaves, (Pl. 5, fig. 5) suggesting that they are in approximately the same position as the branches.

BRANCHING: Alternate, occurring midway between the leaves. Secondary branching not observed.

SPORANGIA: Both the megasporangia and microsporangia sometimes occur on the same sporophyll, or they occur singly. Microsporangia are almost invariably associated with megasporangia, (Pl. 5, figs. 4 & 6), but megasporangia frequently occur without associated microsporangia (Pl. 4, fig. 2, Pl. 5, fig. 3). Microsporangia tend to be concentrated along the main axis of the rhizome (Pl. 4, fig. 4), whereas mega-

sporangia occur not only along the main axis, but also to the tips of lateral branches (Pl. 5, fig. 5). An occasional microsporangium occurs on the branches some distance from the main axis, but these are much reduced in size, being about half the size of those on the main axis.

The microsporangia are enclosed in the enveloping indusium which is ovate to round in outline (Pl. 5, fig. 6) with a short pointed apex (Pl. 5, fig. 6). The microsporophylls range from 0.5 to 1.5 mm long. In many specimens the original polygonal cell pattern of the sporophyll is clearly visible (Pl. 4, fig. 4, Pl. 5, fig. 4).

The indusium on the megasporangium is generally absent except for possibly the more resistant portions in the apical regions. Three metasporangia are present on each sporophyll, even on those associated with the microsporangia (Pl. 4, fig. 4, Pl. 5, figs. 3-4). The size range of the megasporangia is about 0.5 to 1 mm.

DISCUSSION: The fossil record of the water fern Azolla has recently been reviewed by Hills and Weiner (1965). To date, in addition to the six extant species (Svenson, 1944, Rao, 1935), 20 fossil species ranging in age from Maestrichtian to Pleistocene have been described. Species of the genus are divided into 2 sections; section Azolla (formerly Euazolla) and section Rhizosperma. A third section Antiqua was proposed by Dorofeev (1959) to include a typical Rhizosperma type with more than nine floats. This section is here interpreted as an intermediate stage between the other two sections. Section Azolla is characterized by megaspores with three floats and massulae with glochidia, whereas section Rhizosperma is characterized by megaspores with nine floats and massulae without glochidia. Rao's (1935, p. 186) studies of A. pinnata (Section Rhizosperma) indicate that the massulae of A. pinnata are not entirely without glochidia, but that they are poorly developed. The section should, therefore, be characterized by megaspores with nine floats and massulae with or without poorly developed glochidia. The glochidia may be simple, branched or hooked processes which are restricted to areas of contact between adjacent massulae. This feature is important in the

discussion of the relationships of the two sections.

Hills and Weiner (1965) suggest that section Rhizosperma was derived from section Azolla. Section Azolla has a longer geologic history than section Rhizosperma. _A. prisca_ Reid and Chandler, with nine floats and massulae with glochidia, may be interpreted as a transitional form between the two sections, and not as an ancestral form of both types. The fossil evidence suggests that the ancestors of section Rhizosperma originally had well developed glochidia which were lost during evolution. Re-examination of type material of _A. geneseana_ (Maestrichtian) reveals that not all glochidial stalks are tipped with the typical anchor shaped flukes, but occasionally there is one in which the flukes are only partially separated from the stalk. The recent discovery by the writer (at Coalmont, B.C.) of massulae of _A. primaeva_ (middle Eocene) with processes which lack flukes suggest that this latter character was also a feature of these early forms of _Azolla_. Both _A. geneseana_ and _A. primaeva_ are closely allied to members of section _Azolla_ in having three floats and glochidia which generally have the characteristic flukes.

In his studies of the life history of _A. filliculoides_, Campbell (1893, p. 158) noted that during the initial stages of development of the sporangia, both microsporangia and megasporangia were borne on the same sporophyll, but at a later stage either the microsporangia or the megasporangia aborts. Rao (1935, p. 191) noted the same condition in _A. pinnata_. This led him to state that perhaps originally the sporocarps were bisexual. If this be true for _A. pinnata_, then it is probably true for _A. filiculoides_. Bisexuality would be a feature common to both sections expected in the fossil form. Bisexuality is found in the fossil _A. primaeva_ from Driftwood Creek, B.C. In this fossil all three conditions, microsporangia alone, microsporangia and megasporangia together, and megasporangia alone, exist. In this fossil there is present not only the character of bisexual sporocarps postulated for the ancestors of both sections, but also the character of unisexual sporocarps now present in both sections.

Campbell (1893, p. 159) noted that only one megasporangium develops at first,

but (p. 161) when the microsporangium is about half-grown, the outer cells of the stalk grow out into short stalks which are apparently abortive sporangia. He concludes (p. 161) that it can be assumed that Azolla is derived from some form in which there were several megasporangia in the sporocarp. Rao makes no mention of similar papilla in A. pinnata. Therefore, the multi-megasporangiate condition can only be stated as characteristic of section Azolla. In A. primaeva the multi-megasporangiate condition is the rule. In this form three megasporangia are found per sporocarp (Pl. 4, fig. 2).

The problem arises of how to derive the nine-float condition of section Rhizosperma from the three-float condition of section Azolla. A survey of the literature on section Rhizosperma, both fossil and extant, (Rao, 1935; Dorofeev, 1959) indicates that the typical arrangement of floats is in two tiers, an upper containing three floats, and a lower with six floats. The lower 6 are made up of two distinct sets of three. Reid and Chandler (1926, p. 41) make a point of stating that the float arrangement in Azolla prisca is three sets of three, three floats above and six floats below; in other words, the identical arrangement of section Rhizosperma. The relationship of A. prisca with section Rhizosperma is unquestioned with regard to the megaspore. There is proof in A. primaeva that at least some early representatives of Azolla were tri-megasporangiate. Therefore, the nine-float condition may have been obtained by fusion of three megasporangia of A. primaeva, followed by the abortion of two additional megaspores.

Is such a fusion of parts in Azolla possible? No such fusion can be shown for any of the extant species as they are all unimegasporangiate. If we turn to the fossil record, we discover that in A. turgaica Dorofeev (1959), a bisporangiate form, the megaspores are often fused and cannot be separated. Fusion, therefore, is not only possible but is demonstrable.

Once fusion has occurred, will two additional megaspores abort? A. antiqua Dorofeev (1959), generally has six floats but occasionally eight or nine (?) The description fails to reveal the relation of the extra floats to the typical three sets of three,

but they could represent the extra megaspores which have aborted. I think they might be so interpreted, as the remainder go unquestioned as aborted megaspores. Thus the nine-float condition of section Rhizosperma could have been derived from the fusion of three megasporangia of the section Azolla.

The writer accepts the age assignments of the species as presented by various authors. Thus we find A. geneseana (section Azolla) of Maestrichtian age; A. primaeva (section Azolla) middle Eocene; A. antiqua (section antiqua?), late Eocene-early Oligocene; A. prisca (intermediate between section Azolla and section Rhizosperma) Oligocene. Thus the pertinent fossils occur in the correct time sequence for evolution to have occurred as outlined above. Fig. 13 presents in outline form the postulated changes whereby section Rhizosperma was derived from section Azolla.

Noteworthy changes in Azolla are: the reduction in number of sporangia which, in the fossil A. primaeva, occurred on both the main axis and lateral branches and resulted in a single sporangium on the first leaf of a lateral branch; reduction from the tri-megasporangiate condition of A. primaeva to the unimegasporangiate condition of extant species; reduction from bisexual sporocarps of A. primaeva to unisexual sporocarps of extant species.

Present evidence indicates that the first changes occurred in the megaspore in late Eocene times (A. antiqua) and that by Oligocene times the transition to the nine-float condition was complete, i.e. A. turgaica, A. prisca. Dorofeev (1959, p. 1761) states that massulae of A. nana lack glochidia, suggesting that the change from massulae with glochidia to the non-glochidiate condition occurred about the same time. The presence of glochidiate massulae in A. prisca and the poorly developed glochidia of the extant species A. pinnata suggest that the loss of the glochidia was not so abrupt. Dorofeev (1959, p. 1758) states that "Divergence of species into sections in this genus occurred considerably earlier than the Oligocene".

The above postulated divergence into sections in the late Eocene is not entirely

in disagreement, but suggests only that the time of change of the massulae took place later than previously thought.

In summary, it is postulated that section Rhizosperma was derived from section Azolla, and the nine-float condition of section Rhizosperma resulted from the fusion of three megaspores on a single sporocarp (as in A. primaeva). A. antiqua Dorofeev is interpreted as an early stage of fusion, whereas A. prisca represents one of the end products of this fusion. The change from glochidiate to non-glochidiate massulae appears to have taken place later than the changes in the megaspore.

A. teshiana Florschutz (24 floats) and A. schopfi Dijkstra (15 ? floats) of Paleocene age suggest that possibly the path of evolution was somewhat different than postulated above. In A. teschiana the typical arrangement is 6, 9, 9, whereas in A. schopfi the arrangement is irregular. It would be possible in this case to derive section Rhizosperma by loss of floats from 24 in A. teshiana to 15? in A. schopfi to 12 in A. antiqua, with a loss in three more resulting in the typical section Rhizosperma arrangement.

A. teschiana has massulae with well developed non-septate glochidia. If this has been the line of evolution then we must look for the division into the two sections of the genus in the Mesozoic.

An alternate explanation is that A. teshiana and A. schopfi are representative of a third section which is characterized by more than nine floats and which split off from the line, giving rise to the extant species sometime in the Mesozoic.

	Section Azolla	Section Rhizosperma
Recent	*A. mexicana* *A. caroliniana* *A. microphylla* *A. filiculoides*	*A. nilotica* *A. pinnata* - 9 floats massulae with simple branched or irregularly devel. flukes
Pleistocene	*A. filiculoides*	*A. pinnata*
Pliocene	*A. pyrenaca* - 3 floats massulae with glochidia	
Miocene		Loss or reduction of glochidia
U. Olig.		
M. Olig.		*A. prisca* - 9 floats glochidiate massulae
L. Olig.		Reduction of floats
Upper Eocene	Reduction 3 megaspores to 1 megaspore/sporophyll	*A. antiqua* - 9 float megaspore general, however 8-9 (?) observed massulae unknown
M. Eocene	*A. primaeva* - tri-megasporangiate massulae with flukes or elongate processes lacking flukes	Fusion of 3 megaspores & abortion of 2
L. Eocene		
Paleocene		
Maestrichtian	*A. geneseana* - 3 floats- - glochidia on massulae - 2-4 points/fluke	

Figure 11. Suggested phylogenetic sequence in the development of Section Rhizosperma from section Azolla.

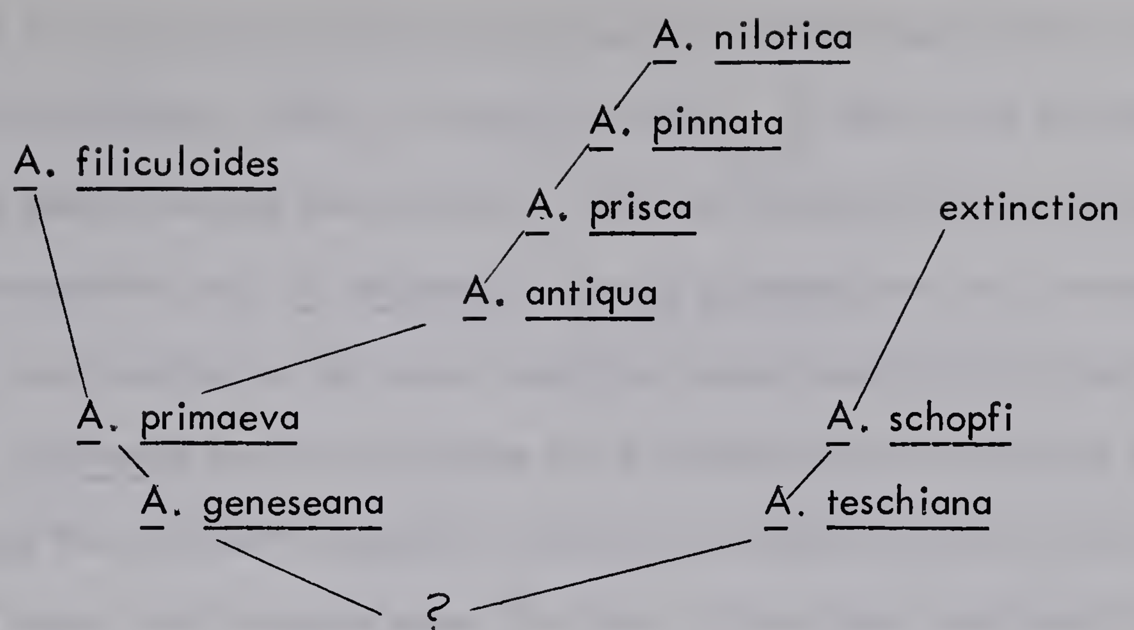


Fig. 12. Evolution trends in Azolla assuming A. schopfi and A. teschiana belonged to a section which has become extinct.

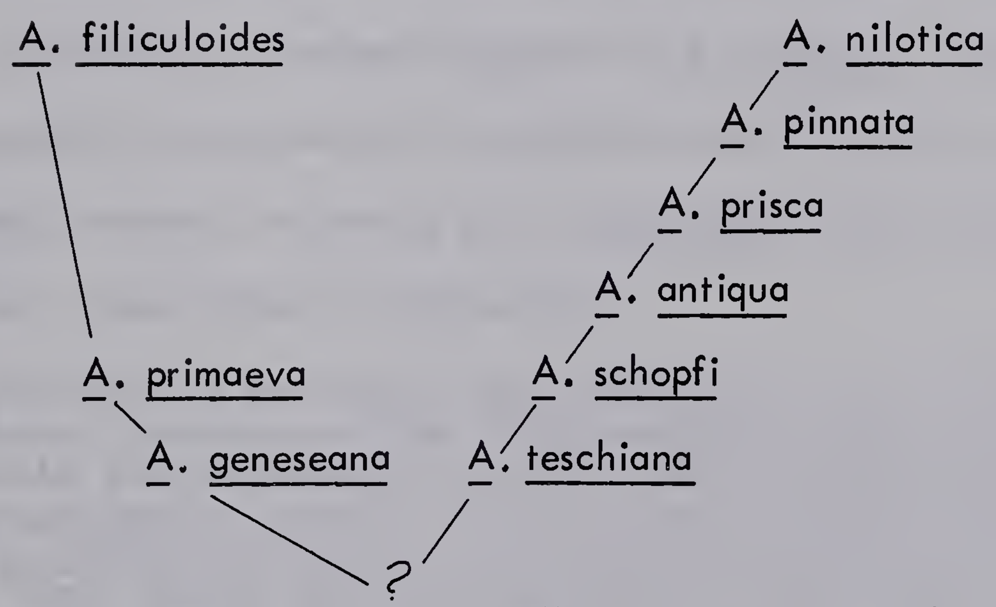


Fig. 13 Evolution trends in Azolla assuming section Rhizosperma was derived from A. teschiana.

The derivation of section Rhizosperma from section Azolla is considered the most likely, because predictable features (bisexual sporocarps, multi-megasporangiate condition) can be demonstrated.

ABUNDANCE AND OCCURRENCE: Azolla primaeva has been found at the following localities: Princeton (Arnold, 1951; Hills, 1962; Rouse, 1962), Nicola Lake;

Quilchena; 3.7 miles west of Williams Lake; Coalmont; Driftwood Creek; and Third Beach, Vancouver (Rouse, 1962), in British Columbia. To date there have been no reports of the species outside the province. Hills and Weiner (1965) consider A. intertrappea as probably conspecific with A. primaeva. Azolla primaeva both as a macrofossil and microfossil is very common at the above localities except possibly Third Beach. At Princeton, A. primaeva occurs only below the Princeton Black Coal Seam; at Coalmont it occurs below the coal seam exposed at the mine workings on Collins Gulch, and at Quilchena it occurs also in strata below the coal. At the other mentioned localities (except Third Beach) it occurs throughout the section.

GEOLOGIC RANGE: The apparent correlation in time of A. primaeva with A. intertrappea with which it is thought to be conspecific (Hills and Weiner 1965), cannot be evaluated at this time, because the age of the Indian strata has not yet been stabilized. The middle Eocene age assignment of A. primaeva is based on associated mammal remains; microfloral correlation with the middle Eocene Green River Formation, Wyoming, and K-Ar dates, whereas, the dating of A. intertrappea is based partly upon the presence of Azolla itself. Sahni (1941, p. 490) states:

"This revival of the Tertiary view dates from the year 1933 when the present writer (see Sahni, Srivastava and Rao, 1934, postscript, p. 27), reviewing the Deccan Flora as a whole, was impressed by its Tertiary aspect, and by the discovery of the modern genera Nipa and Azolla in this flora. As this evidence came from the Nagpur-Chhindwara region, the grounds for assigning a Tertiary age to the traps were particularly strong (Sahni, 1934, 1937, 1938, 59-65). Since then much other evidence from various directions has converged to the same conclusion, with the result that we may now regard this as the view generally accepted".

Therefore, I must conclude that the Eocene assignment of A. intertrappea is speculative.

Table 4 lists the fossil and extant species of Azolla and gives their known geologic range.

There are other features of the genus which are of interest to the palynologist. First, the nine-float condition is not known to be abundant until post-Lower Oligocene time, and second, septate glochidia have not been reported in any of the fossil forms.

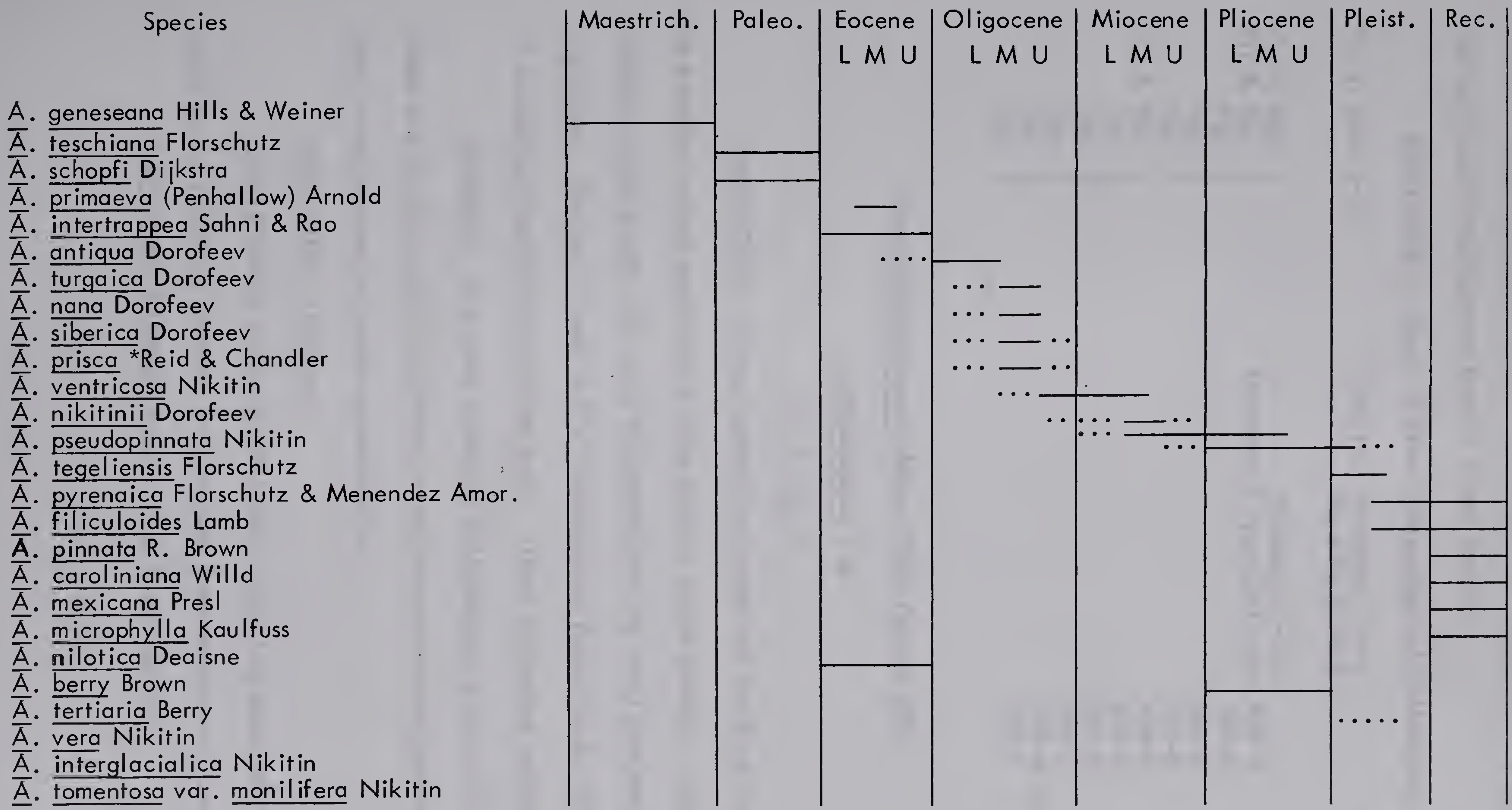


Table 4. Known geologic range of fossil and extant species of Azolla (modified after Dorofeev, 1959).

* Reid and Chandler give Oligocene as the age assignment. A. tertiaria and A. berry are known from vegetative remains only. The age assignments of A. vera, A. tomentosa var. monilifera are unknown to the writer.

To date A. geneseana, A. primaeva, A. tertiara, A. berry and A. schopfi are the only fossil forms reported from in North America.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 3, figs. 8-12	Slide No. Princeton 1-1-1		Co-ord. 120.2/46.5
	Pit 4 #1 3-19-3-1		120.2/54.2
			111.9/45.4
Pl. 6, fig. 1	Princeton 1-1-1		119.9/36.6
Pl. 4, fig. 1	Macrofossil Type Coll. No.	908-A	
fig. 2		909-B	
fig. 3		908-B	
fig. 4		909-B	
Pl. 5, fig. 1		908-C	
fig. 2		908-D	
fig. 3		909-D	
fig. 4		909-E	
fig. 5		909-A (counterparts)	
fig. 6		909-F	

Genus Deltoidospora (Miner 1935) Potonie 1956

Deltoidospora ? sp.

Pl. 6, fig. 2

DIAGNOSIS: Trilete; commissures raised and reaching the equator bordered by a narrow margo; equatorial outline deltoid, apices rhombic. interradials concave; proximal exine smooth (?); exine thickened over the distal pole and extending out towards the apices. The apical ends of this thickening are folded back, giving the appearance of extending completely around the grain. Distal thickening reticulate. Size 26 microns.

REMARKS: This spore resembles Deltoidospora junctum (Kara-Murza) Singh in shape and the distal fold, but differs in that the entire distal surface is thickened and bears a well defined reticulate ornamentation.

AFFINITIES: Unknown.

OCCURRENCE AND ABUNDANCE: Only two grains of this type were observed, one from the Allenby Formation and the other from the strata at Coalmont.

GEOLOGIC RANGE: Known range middle Eocene.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 6, fig. 2	Slide No. T. Pit 4 #1 3-19-7-5	Co-ord. 120.2/43.9

INCERTAE SEDIS

Genus Verrucosisporites Ibrahim 1933 emend. Potonie and Kremp 1954

Verrucosisporites coalmonti n.sp.

Pl. 6, fig. 3-8

DIAGNOSIS: Trilete; circular to oval in equatorial outline; laesurae indistinct, simple slits, extending at least two thirds of the radius of the spore; exine on both surfaces covered by verrucae of irregular size and shape; verrucae on the proximal surface finer than on distal surface, the verrucae range up to six microns in width and 2.5 microns in height. Total size range of the spore 24 to 31 microns (10 measurements) with eight in the 29 to 31 micron range.

REMARKS: The specific epithet is in reference to the type locality.

OCCURRENCE AND ABUNDANCE: Only 10 spores of this type were found in samples from Collins Gulch at Coalmont. They occur 50 to 200 feet stratigraphically above the coal seam.

GEOLOGIC RANGE: The strata at Coalmont are correlated with middle Eocene. Therefore, the known range of this spore is middle Eocene.

TYPE LOCALITY: Strata above the coal adit on Collins Gulch at Coalmont.

HOLOTYPE: Pl. 6, fig. 4 and 5, location TS5-3-3-16-2-3 Co-ord. 116.1/59.4

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 6, figs. 3-8	Slide No. TS5-3-3-16-2-3	Co-ord. 116.1/59.4
		122/48.5
	TS5-3-3-16-3-4	121.9/48

Fern sporangia with annulus (?)

Pl. 6, fig. 9 & 12

DIAGNOSIS: Polycellular ring of thick-walled cells with a distinct basal cell. The basal cell is larger and thick-walled than the remainder, and has a flattened surface where it was attached to the sporangial stalk (?). The size and thickness of the cell walls decrease away from the basal cell, and are thinnest and smallest in the apical region of the sporangium. Cheek cells are thin-walled and elongate radially. Size about 40 microns.

OCCURRENCE AND ABUNDANCE: Three sporangia (?) of this type were found, one from the Allenby Formation at Princeton and two from the strata at Quilchena.

GEOLOGIC RANGE: Known range middle Eocene.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 6, fig. 9 & 12 Slide No. Q3-3-23-12-6 Co-ord. 112/58.5

DIVISION SPERMATOPHYTA

CLASS GYMNOSPERMOPSIDA

ORDER CYCADALES OR GINKGOALES

Genus Cycadopites (Wodehouse 1933) Wilson and Webster 1946

Cycadopites follicularis Wilson and Webster 1946

Pl. 6, fig. 10

1946 Cycadopites follicularis Wilson and Webster, Amer. Jour. Bot., vol. 33, p. 274, fig. 7.

1957 Ginkgo bilobaeformis Zaklinskaya, Acad. Sci. SSSR Works of the Geol. Inst. Contr. 6, Moscow, p. 94, pl. 1, figs. 6-11.

1957 Cycadopites follicularis Rouse (1957) Can. J. Bot. 35, p. 365, pl. 2, fig. 1.

1959 Cycadopites follicularis Rouse (1959) Macropaleo, 5(3) p. 313, pl. 1, fig. 3-4.

1962 Ginkgo sp. Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, p. 91, pl. 27, figs. 1-3.

DIAGNOSIS: Ellipsoidal, approximately twice as long as wide; length 33 to 47 microns; width 14 to 33 microns; furrow extending the full length of the grains, open at both ends, usually closed in the middle by furrow edges overlapping in shrinkage; surface smooth, wall 1.5 microns thick, translucent (modified after Wilson and Webster, 1946, p. 274, see also Rouse 1959).

REMARKS: Wilson and Webster gave a length of 39 to 41 microns and a width from 18 to 21 microns for this species. The specimens studied ranged from 36 to 42 microns in length and 14 to 21 microns in width. In all other features they are identical. Therefore, the size of C. follicularis has been modified.

AFFINITIES: It is common to assign monosulcate grains to the cycads. However, the specimens studied here correspond very closely to pollen of Ginkgo biloba. The presence of leaves of Ginkgo adiantoides suggests that the pollen belongs to this genus rather than to the cycads.

OCCURRENCE AND ABUNDANCE: Rare, less than twenty grains of this type were observed. Present at all localities studied.

GEOLOGIC RANGE: Upper Cretaceous to Eocene. Pollen of this type have been reported from the Paleocene, Fort Union Formation; Paleocene of Russia; middle Eocene Green River Formation. At Princeton they occur in association with mammal remains diagnostic of the middle Eocene.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 6, fig. 10 Slide No. T Pit #1 3-19-25 Co-ord. 126/31.7

Cycadopites sp.

Pl. 6, fig. 11

DIAGNOSIS: Monosulcate, elliptical, approximately twice as long as broad; length 60 to 70 microns, width 31 to 35 microns; sulcus extending the full length of the grain. Exine about one micron thick, levigate to faintly granulose.

REMARKS: This species can be differentiated from C. follicularis by its larger size. It is similar to C. formosus Singh in size and ornamentation with which it may be conspecific.

AFFINITIES: Cycadalean?

OCCURRENCE AND ABUNDANCE: Only three poorly preserved specimens of this type were found at Coalmont, British Columbia.

GEOLOGIC RANGE: Unknown. Strata at Coalmont are correlated with the middle Eocene Allenby Formation at Princeton, British Columbia.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 6, fig. 11 Slide No. T Pit 4 #1 319-5-3 Co-ord. 109.9/51.7

CLASS GYMNOSPERMOPSIDA

ORDER CONIFERALES

FAMILY PINACEAE

Genus Larix Miller 1754 or Pseudotsuga

DIAGNOSIS: Pollen grains circular to oval in outline. Wall levigate, with numerous folds, wrinkles and wedge-shaped splits. Size range 60 to 70 microns (Rouse, 1962, p. 200).

REMARKS: Specimens identical to those described by Rouse (1962) and Hills (1962) as Larix plicatipollenites have been found at all localities. The size range is much larger (50-100) than Rouse reported, and suggests close affinities with Inaperturopollenites magnus Thompson and Pflug (1953, p. 64). These grains are also very similar to Inaperturopollenites cf. magnus sensu Manum 1962.

AFFINITIES: Rouse (1962, p. 200) states that this is the first report of Larix in the Eocene of North America. Manum (1962, p. 40) states that living equivalents are found among the pollen of Larix and Pseudotsuga and that in all probability originated from the Pinaceae, with Larix affinities. Because pollen of Larix and

Pseudotsuga are very similar, they cannot be distinguished in most cases, especially where the size range is large, as in the present case.

OCCURRENCE AND ABUNDANCE: Grains of this type are rare (45 in 4400 grains counted) but are present at all localities. At Princeton and Coalmont they occur throughout the section.

GEOLOGIC RANGE: Pollen of this type probably is of little stratigraphic significance because of the problems of establishing identity with previously described forms. *Inaperturopollenites* cf. *magnus* was described from strata of Paleocene to Eocene age, and *Larix plicatipollenites* has been found only in the Eocene. *Inaperturopollenites magnus* Thompson and Pflug (1953) was reported as common throughout the Tertiary. More work will have to be done on this genus before its stratigraphic significance can be evaluated.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 7, fig. 1 Slide No. TS5-3-16-2-3 Co-ord. 127.5/66.4

FAMILY PINACEAE

Genus *Tsuga* Carriere

Tsuga viridifluminipites Wodehouse

Pl. 7, fig. 2

1933 *Tsuga viridifluminipites* Wodehouse, Bull. Torr. Bot. Club, vol. 60, p. 491, fig. 14.

1934 *Sporites macroserratus* Wolff, Arb. Inst. Palaobot. Berl. 5, p. 67.

1935 *Tsuga* (*canadensis* Typ) Rudolph, Bot. Centralbl. Beih. 54, p. 326.

1938 *Tsuga macroserratus* (Wolff) Thiergart, Shr. Brennstoffgeol. 13, p. 304.

1953 *Zonalapollenites viridifluminipites* Thompson and Pflug, Palaeontographica Abt. B, Bd. 94, p. 67.

1958 *Tsugaepollenites viridifluminipites* Potonie, Geologischen Landesanstalten der Bundesrepublik Deutschland, Beih. Geol. Jb. Haft 23, p. 48.

1962 Tsuga viridifluminipites Rouse, Micropaleontology, vol. 8, no. 2, p. 200, pl. 1, figs. 16-17.

1962 Tsuga viridifluminipites Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, p. 92.

DIAGNOSIS: Apparently nearly spherical in original form, 47 to 78 microns in diameter. The entire proximal surface covered with uniformly deep convolutions. Distal surface smooth to slightly convolute (modified after Wodehouse, 1933, p. 491).

REMARKS: Wodehouse based his description on a single specimen, whereas Rouse (p. 200) states that he observed about 100 grains ranging from 47 to 70 microns in diameter. The grains encountered here range from 55 to 70 microns.

AFFINITIES: Both Wodehouse and Rouse state that pollen of this type is very similar to the extant species T. canadensis.

OCCURRENCE AND ABUNDANCE: Rare; encountered at Princeton, Coalmont, and Driftwood Creek. Only two grains of this type were found in a total count of 4400 grains from the Allenby Formation.

GEOLOGIC RANGE: Pollen of this type has been reported from the middle Eocene Green River Formation, and is found in association with mammal remains indicative of the middle Eocene in the Allenby Formation.

Genus Picea Dietrich 1824

Picea alipollenites Rouse

Not illus

1962 Picea alipollenites Rouse, Micropaleontology, vol. 8, no. 2, p. 200, pl. 1, fig. 19-20.

DIAGNOSIS: Bisaccate, central body ill-defined and circular; bladders well developed, about equal to the central body in size; junction with central body poorly defined; marginal crest occasionally present; ornamentation cap granular to reticulate,

bladders coarsely and irregularly reticulate, germinal furrow smooth to granular. Germinal furrow broadest at the distal pole narrowing towards the equator. Size range; total breadth 94 to 109 microns; breadth of central body 60 to 65 microns; breadth of bladders 44 to 55 microns; length of central body 52 to 65 microns; length of bladders 55 to 65 microns. Exine about 1.5 microns thick on the bladders and about 2.5 microns thick on the proximal cap.

Total Breadth	Breadth Central Body	Breadth Bladders	Length Central Body	Length Bladders
107	60	45-55	60	55-55
101	60	49-49	52	65
109	65	44-44	65	65-65
94	60	44-47	60	57-60

Table 5. Dimensions in microns of 4 typical grains of Picea alipollenites.

REMARKS: The above definition is based entirely on specimens encountered in this study.

AFFINITIES: Picea. Coniferales.

OCCURRENCE AND ABUNDANCE: Present at all localities studied. Comprises about 10 to 15 percent of the bisaccate grains, and hence about two percent of the total pollen.

GEOLOGIC RANGE: Known range middle Eocene - Allenby Formation, Princeton.

Picea cf. grandivescipites Wodehouse

Pl. 7, fig. 3

1933 Picea grandivescipites Wodehouse, Bull. Torr. Bot. Club, vol. 60, p. 488, fig. 10.

1946 Picea grandivescipites Wilson and Webster, Amer. Jour. Bot., vol. 33, p. 275, fig. 8.

1957 P. grandivescipites Rouse, Can. J. Bot., vol. 35, p. 368, pl. 2, figs. 11 & 12.

DIAGNOSIS: Bisaccate; central body round to rounded rectangular; bladders distally pendant, rounded in outline; 34 to 49 microns in breadth, 52 to 65 microns in length, irregularly reticulate to granular; central body 55 to 65 microns in breadth, 57 to 65 microns in length; proximal cap coarse granular and about 2 microns thick; germinal furrow 10 to 16 microns broad, smooth; total breadth 81 to 114 depending on compression.

Total Breadth	Breadth Central Body	Breadth Bladders	Length Central Body	Length Bladders
107	57	39-47	57	52-57
91	65	42-46		
81	62	34-47		
88	60	39-44	62	
101	65	44-49	65	62
91	55	44-47	62	49

Table 6. Measurements in microns of 6 typical specimens of Picea cf. grandivescipites.

REMARKS: This type of pollen grain is very similar to P. grandivescipites except in the dimensions, which are somewhat smaller than indicated by Wodehouse. It is also similar to P. alipollenites Rouse, differing only in size. It is uncertain if Rouse's dimensions refer to the total length of the grain or to the central body. If the measurements are total length, then the specimens studied in this thesis are identical. Rouse (personal communication states that in his opinion this is a Pinus and very close to P. strobipites Wodehouse.

AFFINITIES: Grains of this type unquestionably belong to the Pinaceae. Assignment to Picea is generally based on the size of the pollen grain, the confluence of bladders and body, and reticulate patterns.

OCCURRENCE AND ABUNDANCE: Three hundred and twelve grains of this type were encountered in a total of 4400 grains. Pollen of this type is found in all sections studied, and occurs throughout the sections.

GEOLOGIC RANGE: Wilson and Webster (1946, p. 275) state that P. grandivescipites is rare in the Fort Union (Paleocene). Wodehouse (1933, p. 488) states that he found only six grains of this type in the Green River Formation (middle Eocene). Its occurrence in both the Allenby and Burrard (Eocene) give a total range of Paleocene - Eocene. There is every chance that identical pollen occurs in later Tertiary strata of North America, as Picea pollen has been reported in the Miocene by Gray (in Chaney and Axelrod 1959, Wolfe (1962) and Mathews and Rouse 1963).

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 7, fig. 3	Slide No. T Pit 4 #3 319-7-5	Co-ord. 112.2/43.8

Abietineaepollenites Potonie 1958

Abietineaepollenites sp.

Pl. 7, fig. 4-6

DIAGNOSIS: Bisaccate; central body oval, breadth greater than length, breadth 104 to 130 microns, length 94 to 107 microns, dorsoventral compressions oval to rounded, breadth 109 to 163 microns, bladders distally pendant, not clearly differentiated from the central body on the proximal surface, separated on the distal surface by a poorly-defined but distinct germinal furrow, breadth 49 to 68 microns, length equal to the length of the body, germinal furrow 6 to 13 microns broad, granular to smooth. The bladders and central body are pseudoreticulate, canals radial, reticulate or irregularly arranged. Ornamentation on central body distinctly finer than on the bladders. Exine thickness about two to three microns on the cap, less on the bladders.

REMARKS: This species is very similar to Abies concoloripites (Wodehouse 1933, p. 490) with which it may be conspecific. However, it is uncertain as to whether

Wodehouse's measurements refer to the central body or to the total length of the grain. This species is distinctly larger than any of the types described by Manum (1962, p. 33). It can also be differentiated from the latter's species by the pseudoreticulate ornamentation as opposed to reticulate ornamentation.

AFFINITIES: Probably the closest modern ally is Abies. Rouse (personal communication) states that in his opinion this pollen is affiliated with Picea or Cedrus. It is here retained within the form genus until positive assignment can be made.

OCCURRENCE AND ABUNDANCE: Present at all localities and appears throughout the section. It is, however, never very common. Pollen of this type usually occurs in clusters which suggest that the trees grew near to the site of deposition.

GEOLOGIC RANGE: Mammal remains in the Allenby Formation indicate a middle Eocene age for these deposits. The similarity with forms from the middle Eocene Green River Formation also indicates this age.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 7, figs. 4-6	Slide No. TS5-1-3-17-1-5	Co-ord.	116.2/58
	TS5-1-1-3-17-1-5		125.3/56.8
	TS5-1-3-17-1-5		117.2/57.9

Genus Alisporites Daugherty 1941 rest., Potonie and Kremp 1956

Alisporites sp.

DIAGNOSIS: Bisaccate; central body well defined, oval; bladders fused, longer than the central body; bladders and central body irregularly finely reticulate; germinal furrow about 14 microns wide extending beyond the central body onto the bladders. Size: total breadth 122 microns; breadth of central body 83 microns; breadth of bladders 52 to 55 microns; length of central body 79 microns; length of bladders 88 microns.

REMARKS: This pollen appears to be monosaccate under low magnification, but is clearly bisaccate under higher magnification. The bladders are fused on the

proximal surface only, whereas on the distal surface they are separated by the germinal furrow.

AFFINITIES: Probably with the family Pinaceae.

OCCURRENCE AND ABUNDANCE: Only a single specimen of this type was observed at Coalmont, British Columbia.

GEOLOGIC RANGE: Known range middle Eocene. The strata at Coalmont are correlated palynologically with the Allenby Formation at Princeton which contains mammal remains indicative of middle Eocene age.

ORDER CONIFERALES

Genus Pityosporites (Seward 1914) emend. Manum 1960

Pityosporites cf. alatipollenites (Rouse) Singh 1964

Pl. 8, fig. 1

1964 Pityosporites alatipollenites Singh, Research Council of Alberta, Bull. 15, p. 123, pl. 16, fig. 10.

1959 Pinus alatipollenites Rouse, Micropaleontology, vol. 5, p. 314, pl. 1, fig. 7.

DIAGNOSIS: Bisaccate pollen grains, bladders distally pendant, slightly constricted towards the base, diverging bladders small as compared to the body; germinal furrow about six microns wide; central body elliptical, broader than long; total breadth 57 microns, breadth of central body 39 to 44 microns, breadth of bladders 26 to 29 microns; length of central body about 39 microns; length of bladders about 30 microns. Exine smooth to granular.

REMARKS: Pollen of this type is similar to, but not identical, to P. alatipollenites. It differs from the latter in its smaller dimensions and smoother exine.

AFFINITIES: Uncertain Pinaceae?

OCCURRENCE AND ABUNDANCE: Rare, only two pollen grains of this type

were encountered at Coalmont.

GEOLOGIC RANGE: Strata at Coalmont are correlated palynologically with the middle Eocene Allenby Formation at Princeton.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 8, fig. 1 Slide No. TS5-1-3-17-1-5 Co-ord. 124.1/49.5

Pityosporites elongatus n. sp.

Pl. 8, fig. 2-4

1962 Pinus sp. Hills, Unpubl. M.Sc., Thesis, Univ. of British Columbia, p. 96, pl. 28, fig. 2.

DIAGNOSIS: Bisaccate; central body rectangular to rounded-rectangular, marginal crest sometimes present but thin (?); bladders well developed, distally pendant; length greater than breadth; length of central body greater than breadth; total breadth 68 to 91 microns; breadth of central body 44 to 49 microns; breadth of bladders 31 to 42 microns; length of central body 62 to 74 microns; length of bladders 52 to 65 microns, germinal furrow parallel-sided or expanding at the ends, 6 to 12 microns in width, smooth to granular ornamentation; proximal cap distinctly granular and thin (?); bladders reticulate, maximum lumen diameter three microns, mesh finer approaching central body. Exine thickness uniform on both the bladders and central body, less than two microns.

Total Breadth	Breadth Central Body	Breadth Bladders	Length Central Body	Length Bladders
68	44	36-42	74	65
81	49	34-39	65	52
78	49	31-34	70	57
88	52	39	68	60
88	52	36-42	62	52
91	49	39-42	70	65

Table 7. Dimensions in microns of six typical grains of Pityosporites elongatus.

REMARKS: The specific name refers to the elongate shape of the central body.

AFFINITIES: Pinaceae. Picea?

OCCURRENCE AND ABUNDANCE: Present at Princeton, Coalmont and Driftwood Creek, Nicola Mamitt Rd., McAbee and Tranquille beds. Rare, less than 100 grains of this type were observed in the entire study.

GEOLOGIC RANGE: Known range middle Eocene based on associated mammal remains in the Allenby Formation at Princeton and K-Ar dates.

TYPE LOCALITY: Strata above the coal adit on Collins Gulch at Coalmont, B.C.

HOLOTYPE: Pl. 8, fig. 2, TS5-1-3-17-1-5 Co-ord. 123.7/53

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 8, figs. 2 & 3	Slide No. TS5-1-3-17-1-5	Co-ord. 123.7/53
	TS5-3-3-16-2-3	112.7/66.8
fig. 4	Princeton, comparison Hills, 1962, M.Sc. thesis.	

Pityosporites magnus n. sp.

Pl. 8, fig. 5

DIAGNOSIS: Bisaccate; central body rectangular to rounded rectangular; bladders distally pendant, about equal length to the body, pseudoreticulate, i.e. a reticulate pattern of anastomosing canals rather than ridges; breadth of bladders 57 to 70 microns, length of bladders 107 to 109 microns; central body with pseudoreticulate sculpturing finer than on bladders; exine about 5 microns thick; breadth of body 99 to 114 microns, length of body about 107 microns, height 52 microns; germinal furrow 26 microns in width, parallel sided, smooth to punctate. Total size 133 to 148 microns, depending on position of bladders. Marginal crest not observed.

Total Breadth	Breadth Central Body	Breadth Bladders	Length Central Body	Length Bladders	Height Central Body	Germinal Furrow
148	104	55-70			52	26
133	112	59-65			52	
143	99	67-70	107	104-109		
138	114	52-56				26

Table 8. Measurements in microns of four typical specimens of Pityosporites magnus.

REMARKS: There is a possibility that this species is conspecific with the larger specimens of Picea alipollenites Rouse. There is, however, a distinct size break between specimens referred here to P. grandivescipites Wodehouse and P. alipollenites Rouse. The specific epithet is in reference to the large size of the grain. Rouse (personal communication) suggests that this grain might best be assigned to Piceapollenites.

AFFINITIES: This pollen probably belongs with the Pinaceae and more specifically with Abies or Picea.

OCCURRENCE AND ABUNDANCE: Pollen of this type is present in all sections studied and occurs throughout the section. It comprises less than one percent of the total pollen, but locally is the dominant form. It frequently occurs in clusters suggesting that trees grew very close to the site of deposition.

GEOLOGIC RANGE: Middle Eocene.

TYPE LOCALITY: Strata above the Coal adit on Collins Gulch, Coalmont, B.C.

HOLOTYPE: Pl. 8, fig. 5, Slide TS5-1-3-17-3-7 Co-ord. 118/40.4

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 8, fig. 5 Slide No. TS5-1-3-17-3-7 Co-ord. 118/40.4

<u>Pityosporites</u> sp.
Pl. 8, fig. 6

DIAGNOSIS: Bisaccate; central body circular to oval, bladders distally pendant, longer than central body, irregularly pseudoreticulate (canals as opposed to muri), breadth of bladders 36 to 44 microns, length of bladders 57 to 68 microns, central body cap coarse granular to scabrate, breadth of central body 47 to 52 microns, length of central body 42 to 52 microns, marginal crest well developed and about six microns wide; exine on central body about two microns, on bladders about one micron; germinal furrow smooth to punctate, parallel sided to broadest at the distal pole.

REMARKS: The three grains assigned to this species may belong to two natural species. In size this form is about midway between Type A and Type B, (Manum, 1962, p. 37).

AFFINITIES: Pinaceae?

OCCURRENCE AND ABUNDANCE: Only 3 grains of this type were encountered at Coalmont, British Columbia.

GEOLOGIC RANGE: Middle Eocene? based on correlation with the Allenby Formation at Princeton.

<u>Pityosporites</u> sp.
Pl. 9, fig. 1-2

DIAGNOSIS: Bisaccate; central body oval; bladders distally pendant and diverging, pseudoreticulate (i.e. anastomosing canals), canals tend to be radial, become finer towards the point of attachment; breadth of bladders 52 to 60 microns; length of bladders 62 microns; central body coarse granular to pseudoreticulate, breadth about 68 microns, length about 55 microns; exine of proximal cap about two microns, whereas on the bladders it is about one micron; germinal furrow about five microns wide by 26 microns long.

REMARKS: This species of <u>Pityosporites</u> can be differentiated from the others by the extreme constriction of the bladders and the short germinal furrow.

AFFINITIES: Pinaceae, probably *Picea*.

OCCURRENCE AND ABUNDANCE: Only a single specimen of this type was encountered about 50 feet stratigraphically above the coal seam on Collins Gulch (Coalmont).

GEOLOGIC RANGE: The strata at Coalmont are correlated palynologically with the Allenby Formation which is considered to be Middle Eocene on the basis of mammal remains and K-Ar dates.

DIVISION SPERMATOPHYTA

CLASS GYMNOSPERMOPSIDA

ORDER CONIFERALES

FAMILY PODOCARPACEAE

Genus *Podocarpidites* Cookson 1947 ex Couper 1953

Podocarpidites cf. *ornatus* Pocock 1962

Pl. 9, fig. 3

1962 *Podocarpidites ornatus* Pocock, Palaeontographica Bd. 111, Abt. B, p. 67, pl. 11, fig. 164-166.

DIAGNOSIS: Bisaccate; equatorial outline subcircular to circular with crenulate margins. Length (42 microns) of the central body about equal to the breadth (44 microns); marginal crest about eight microns wide; breadth of the bladders (34 to 44 microns) about equal to the breadth of the central body; bladder length (52 to 55 microns) distinctly longer than the central body; bladders distally pendant; bladder ornamentation irregularly reticulate to radially striate; distal furrow narrow, parallel sided and granular; proximal cap granulose.

REMARKS: This species is similar to, but not identical with *P. ornatus*, differing in breadth to length ratios and total size.

AFFINITIES: Bisaccate grains of this type clearly are fossil representatives

of the extant genus Podocarpus.

OCCURRENCE AND ABUNDANCE: Only a single grain of this type was found above the coal seam on Collins Gulch at Coalmont, British Columbia.

GEOLOGIC RANGE: The strata at Coalmont are correlated with the Allenby Formation of middle Eocene age.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 9, fig. 3 Slide No. TS5-1-3-17-1-5 Co-ord. 122.2/41

Genus Podocarpus L'Heritier ex Persoon 1807

Podocarpus sp.

Not illus

DIAGNOSIS: Bisaccate, equatorial outline of central body oval with a crenulate margin; length of central body (27 microns) less than the breadth (34 microns); length of the bladders about equal to the breadth of the central body, and greater than the length of the body; bladder distally pendant; marginal crest well developed. Ornamentation; bladders irregularly reticulate to granular; proximal cap distinctly granular; germinal furrow smooth to granular. Total length 70 microns.

REMARKS: This specimen is larger and more elongate than the specimen illustrated by Rouse (1962) and occurring in strata correlated with the sediments studied.

AFFINITIES: Grains of this type clearly belong to the extant genus Podocarpus.

OCCURRENCE AND ABUNDANCE: Only a single specimen of this type was found at Coalmont, British Columbia.

GEOLOGIC RANGE: Unknown. Sediments at Coalmont are correlated with the middle Eocene Allenby Formation at Princeton, British Columbia. The genus Podocarpus has not been reported to my knowledge from post-Eocene strata in North America.

FAMILY PODOCARPACEAE

Genus Phyllocladidites (Cookson 1947) ex Couper 1953

Phyllocladidites sp.

Not illus

DIAGNOSIS: Bisaccate; central body oval (?) to round, proximal cap ornamented by coarse granules or fine verrucae; bladders reduced, smooth; distally pendant; germinal furrow smooth, parallel-sided, and about five microns wide; exine on cap less than two microns thick whereas on the bladder it is about one micron thick. Size: breadth of central body 60 microns; length of central body 70 microns; breadth of bladders 21 to 24 microns; length of bladders 47 microns.

REMARKS: This pollen is very similar in size and shape to both Phyllocladidites sp. Singh (1964, p. 114, pl. 15, fig. 10) and Podocarpidites octagoensis Couper (1953, p. 37, pl. 4, fig. 41), differing from both in having a distinctly thinner exine.

AFFINITIES: Grains of this type clearly are fossil representatives of the extant genus Dacrydium.

OCCURRENCE AND ABUNDANCE: Only a single grain of this type was found at Coalmont, British Columbia.

GEOLOGIC RANGE: Strata at Coalmont are correlated with the middle Eocene Allenby Formation at Princeton, British Columbia. However, the similarity of this grain to Phyllocladites sp. Singh (1964) and Podocarpidites octagoensis Couper (1953) suggests a much longer geological range, Lower Cretaceous to middle Eocene?

FAMILY TAXOXIDIACEAE

Genus Taxodium Richard 1910

Taxodium hiatipites Wodehouse 1933

Pl. 9, Fig. 4-8, Pl. 10, Fig. 1

1933 Taxodium hiatipites Wodehouse, Bull. Torr Bot. Club, vol. 60, p. 493, fig. 17.

1931 ? Pollenites hiatus Potonie Jahrb., Preuss Geol Landesanstalt (Berlin), vol. 52, pp. 1-7.

1938 ? Typ Cupressineae 28 Kostyniuk, Botanika Pierurza Zuiazkowa Druknaria we Lwouie, UL. Lindego L.4

1940 cf. Taxodium Thiergart, Breenstoff-Geologie, Stuttgart.

1946 T. hiatipites Wilson and Webster, Amer. Journal, Bot., vol. 33, No. 4, p. 275, fig. 6.

1949 ? Taxodieen-typ (P. hiatus, R. Pot.), Thiergart, Palaeontographica B. 89.

1950 ? Taxodioidites hiatus Potonie, Thompson and Thiergart, Geol Jahrb 65, 35-70.

1950 Taxodium hiatipites Saulnier, Unpubl. M.Sc Thesis, Univ. of Mass., p. 35, pl. 2, fig. 9

1953 Taxodioidites hiatus Hunger, Freiberger Forschungshefte Reihe, C , Angewandte Naturwissenshaften Heft 8 Geologie.

1953 ? Thuyopsis coraceous (Naumova) Bolkovitina, Trudy Inst. Geol. Nauk, Akad. S.S.S.R. 145, Geol. Ser. No. 61.

1953 ? Inaperturo pollenites hiatus (R Pot.) Thompson and Pflug, Paleontographica, vol 90, Pt. B

1957 Taxodium hiatipites Rouse, Can Jour Bot , vol 35, no 3, p 366

1962 T. hiatipites Rouse, Micropaleontology, vol. 8, no. 2, p. 201, pl 2, fig 6

1962 T. distichiforme Simpson, Roy Soc. Edin. Trans. vol 64, no. 16, p. 29, pl. 1, fig. 8.

1962 T. hiatipites Hills, Unpubl. M Sc Thesis, Univ of British Columbia, pp. 99-100, pl. 29, fig 2.

DIAGNOSIS: (Acc. to Wodehouse, 1933, p. 493) "The split and empty exines of grains which seem in all probability to be those of species of Taxodium. The cleft generally bisects the grain almost completely, but the two halves remain joined at their bases, and opening generally without much buckling, though sometimes one of the halves may be crumpled. In size, measured from the tip to the base of one of the halves where it remains joined to its neighbouring half 29.6-37.6μ. The number and arrangement of the surface flecks also match perfectly".

REMARKS: Specimens from the Tertiary deposits studied in this thesis are identical to those of Wodehouse.

Simpson (1962) described 71 new species of fossil sporomorphs belonging to 51 genera. Included amongst these is T. distichiforme which is in my opinion identical to T. hiatipites Wodehouse. Simpson's failure to consult palynological literature limits the usefulness of his publication.

OCCURRENCE AND ABUNDANCE: Present in all samples studied. At Princeton it is most abundant above the Princeton Black Coal seam. At Coalmont it is most abundant (sometimes exceeding 90%) above the coal seam on Collins Gulch. Rouse (1962) reports it from the Burrard Formation at Vancouver.

AFFINITIES; Wodehouse (1933, p. 493) states that these grains could be matched exactly with the extant species T. distichum. However, there is the possibility that their true affinity lies with Juniperus or Libocedrus. Rouse (1962, p. 201) points out that specimens from the Burrard Formation are identical to those from the Green River, although Taxodium macrofossils have not been recorded from either locality. Hills (1962, p. 100) suggested that the scabrate texture of the exine was very similar to that of Libocedrus decurrens and that possibly both Taxodium and Libocedrus pollen were included within this genus. Wilson and Webster (1946) note that the macrofossil T. occidentale Newberry is listed by Knowlton (1919) as being present in the Ft. Union series. Undoubtedly some, possibly all, grains assigned to T. hiatipites truly are derived

from Taxodium, although this has not been proven, and it is essential that this fact be kept in mind when assigning paleoecological significance to this species.

GEOLOGIC RANGE: Taxodium hiatipites has been reported in North America in strata ranging in age from Upper Cretaceous (Rouse, 1957, p. 366); Paleocene, Wilson and Webster (1946, p. 275); Eocene, Wodehouse (1933, p. 493). A similar form Pollenites hiatus has been reported in Miocene and Pliocene strata of Europe by Potonie (1934), Potonie and Venetz (1934), and Wolff (1934). This would suggest that the species is of little use stratigraphically, however, it is the writer's experience that its greatest development in North America is in strata of Paleocene and Eocene age. The writer has observed a number of specimens of this species from Senonian strata on Bathurst Island in the Canadian Arctic. These specimens were smoother than the British Columbia specimens, suggesting that the degree of ornament development may be of stratigraphic value.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 9, figs. 4-8	Slide No. TS5-3-3-16-2-3-	Co-ord. 124/55.3 118.5/47.8 119.6/52.4
Pl. 10, fig. 1	Slide No.	

ORDER CONIFERALES

FAMILY TAXODIACEAE

Genus Sequoia pollenites Thiergart 1938

Sequoia pollenites papillapollenites Rouse 1962 N. Comb.

Pl. 10, fig. 2-7

1962 Metasequoia papillapollenites Rouse, Micropaleontology, vol. 8, No. 2, p. 201, p. 12, fig. 5.

1962 Metasequoia papillapollenites Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, p. 99, pl. 29, fig. 1.

DIAGNOSIS: Pollen circular in outline, with a prominent papilla from two to six microns in length. Ornamentation faintly to fine granulose. The distal surface (with papilla) distinctly thinner and smoother than the proximal cap. Size 20 to 34 microns (modified after Rouse, 1962, p. 201).

REMARKS: The present work indicates that the size ranges from 20 to 36 microns with about 66 percent in the 29 to 32 micron range; 17.5 percent less than 29 microns, the majority of these fall in the 24 to 29 micron range; 16.5 percent larger than 32 microns. Only a single grain larger than 34 microns was found.

The following table lists the pollen characteristics of the Taxodiaceae as determined by Van Campo-Duplan (1951, p. 10-11).

TABLE 9

POLLEN CHARACTERISTICS OF THE TAXODIACEAE (Mod. after Van Campo-Duplan). Measurements in microns.

Av. height in microns	Exine	Papilla	Genus
36 - 39	regularly arranged verrucae	absent	Sciadopitys
36 - 39	fine granulations	very reduced	Cunninghamia
36 - 39	dense granular	about 3 microns	Sequoia
25 - 30	fine granular	up to 11 microns	Wellingtonia
25 - 30	fine granular	broader than long	Glyptostrobus
25 - 30	fine granular	to 5 microns	Cryptomeria
25 - 30	fine granular	to 5 "	Taiwania
25 - 30	fine granular	to 4 "	Athrotaxis
25 - 30	fine granular	to 3 "	Metasequoia
25 - 30	fine to coarse granular	very reduced	Taxodium

The length of the papilla would suggest that the pollen of M. papillapollenites might belong to any of the following genera: Metasequoia, Arthrotaxis, Sequoia, Glyptostrobus, Taiwania or Cryptomeria. The erect papilla would indicate that of these, Sequoia Glyptostrobus and Cryptomeria are unlikely because they have curved papillae and different ornamentation. Therefore, the assignment of this fossil pollen to Metasequoia is doubtful. Manum (1962, p. 43-44) avoided the problem by using the form genus Sequoiapollenites Thiergart for all pollen belonging to the Taxodiaceae. This may be the most satisfactory solution.

Megafossils of Metasequoia have been found at all of the localities studied.

The species Inaperturopollenites polyformosus Thompson and Pflug clearly belongs to the Taxodiaceae. It is distinctly different from the specimens which have curved papillae.

AFFINITIES: Grains undoubtedly belonging to the Taxodiaceae but of doubtful generic assignment.

OCCURRENCE AND ABUNDANCE: Only six grains were counted in 4400 at Princeton, British Columbia. Grains of this type are common in strata at Coalmont and rare at the other localities. Pollen clusters were found at Coalmont, indicating that the trees grew close to the site of deposition.

GEOLOGIC RANGE: The geologic range of papillate pollen is from Late Cretaceous to Recent. Late Cretaceous forms have a longer papilla than sequoia pollenites papilla pollenites averaging about 7 microns. Manum (1962, p. 44) states: "It is noteworthy that none of observed specimens possesses a prominent and more or less bent papilla like that of Sequoia or Cryptomeria". This is the same condition found in the present study. However, Thompson and Pflug indicate that a curved papilla is common in strata of post-Eocene age.

The present evidence suggests that the type studied is indicative of the Paleocene or Eocene. If it is found in association with grains with curved papillae, then a post-

Eocene age is suggested.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 10, figs. 2-7	Slide No. TS5-3-16-2-3	Co-ord. 120.4/56.8
	TS5-3-16-1-2	113.7/52.4
	TS3-3-16-2-3	118.1/51
		118/50.6

FAMILY TAXODIACEAE

Genus *Cunninghamia*

Cunninghamia concedipites Wodehouse 1933

Pl. 10, fig. 8-10

1933 *Cunninghamia concedipites* Wodehouse Torr. Bot. Club, vol. 60, p. 495, fig. 19.

DIAGNOSIS: Unruptured exines of pollen grains, 32 to 37 microns in diameter, thin and collapsing irregularly without predetermined folds. Outer surface covered with minute flecks closely but irregularly packed or smooth. With or without rounded papillae.

REMARKS: Specimens identical to those described by Wodehouse were seen in samples from Coalmont, British Columbia, except for a slightly larger size (up to 45 microns).

AFFINITIES: Wodehouse states that grains of this species are very similar to the extant species *C. sinensis*. The presence of the papillate pores would indicate affinities with members of the Taxodiaceae.

OCCURRENCE AND ABUNDANCE: Rare, only two grains of this type were found at Coalmont.

GEOLOGIC RANGE: Middle Eocene?

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 10, figs. 8-10	Slide No. TS5-3-16-2-3	Co-ord. 124/65
	TS5-3-16-1-2	124.8/58.3
		120.2/43.1

FAMILY TAXODIACEAE (?)

Genus Taxodiaceaepollenites Kremp 1949

Taxodiaceaepollenites sp.

Pl. 10, fig. 11-12

DIAGNOSIS: Grains originally spherical; characteristically split; exine with circular thickened muri which give the grain an undulose outline. The size ranges from 25 to 35 microns.

REMARKS: This species can be differentiated from Taxodium hiatipites by the undulose outline and the non-scabrate texture of the exine. The manner of rupture suggests relationship to the Taxodiaceae, but generic affinities are uncertain.

AFFINITIES: Taxodiaceae (?).

OCCURRENCE AND ABUNDANCE: Rare, but is present above the Princeton Black Coal Seam, above the coal seam on Collins Gulch (Coalmont), and in strata above the coal seam at Quilchena. Grains of this type did not appear in a total count of 4400.

GEOLOGIC RANGE: Middle Eocene.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 10, figs. 11 & 12 Slide No. TS5-2-3-17-12-3 Co-ord. 115.5/59.9

SUBCLASS DICOTYLEDONIDAE

ORDER FAGALES

FAMILY BETULACEAE

Genus Betula Linnaeus 1753

Betula claripites Wodehouse 1933

Pl. 10, fig. 13, Pl. 11, figs. 1-3

1933 Betula claripites Wodehouse, Bull. Torr. Bot. Club, vol. 60, p. 509, fig. 41.

1946 Betula claripites Wilson and Webster, Amer. Jour. Bot., vol. 33, p. 275, fig. 12.

1950 Betula claripites Saulnier, Unpubl. M.Sc. Thesis, Univ.of Mass., p. 39, pl. 3, fig. 4.

1962 ? Triporates Type A Manum, Norsk Polarinstitutt Skrifter, nr. 125, p. 59, pl. 15, figs. 3-9, text fig. 22, b.

1962 Betula claripites Hills, Unpubl. M.Sc. Thesis. Univ. of British Columbia, p. 102, pl. 29, fig. 11-12.

DIAGNOSIS: Apparently spheroidal or oblately flattened in life, 26 to 32 microns in diameter; pores three, protruding owing to the thickening of the exine surrounding them, pore pattern corresponding to the Betula type, apertures approximately circular, aspids faintly visible, texture smooth (modified after Wodehouse 1933, p. 509).

REMARKS: Wilson and Webster expanded the size range to 32 microns. Measurements made during this study confirm the expanded size range. In all other respects the pollen are identical. Manum (1962, p. 59) describes forms which are similar to, if not identical to B. claripites. Trivestibulopollenites betuloides Thompson and Pflug is similar to but much smaller than the specimens studied.

OCCURRENCE AND ABUNDANCE: Rare; only six grains of this type were encountered in a total count of 4400 grains. They have been identified from all deposits studied and appear throughout the section.

GEOLOGIC RANGE: Betula type pollen have been reported from Upper Albian sediments (Bolkhovitina, 1953) through to the Recent. The writer has observed Betula type pollen in the Cenomanian Dunvegan Formation and Senonian strata of Bathurst Island, Canadian Arctic (both unpublished). Wilson and Webster (1946) report Betula claripites Wodehouse from the Paleocene Fort Union Formation. Wodehouse first reported this species from the middle Eocene Green River Formation. Although Wolfe (1962, p. 84) reports Betula in Miocene sediments of Oregon, it was not assigned to a species. Therefore, B. claripites has a known range Paleocene to Eocene.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 10, fig. 13	Slide No. TS5-1-3-17-1-5	Co-ord. 118/37.5
Pl. 11, figs. 1-3	TS5-1-3-17-1-5	118/37.5
	TS5-1-3-16-2-3	116.3/42.5
		121/8/45

Genus Alnus Miller 1933

Alnus quadrapollenites Rouse 1962

Pl. 11, fig. 4-9

1962 Alnus quadrapollenites Rouse, Micropaleontology, vol. 8, no. 2, p. 202, pl. 2, figs. 9 and 36.

1931 Alnipollenites verus Potonie, (non the non four pored forms), Brennesteine Preuss Geol. Landesanstalt Berlin, Bd. 4, p. 58.

1933 Alnus speciipites Wodehouse (non the non four pored forms), Bull. Torr. Bot. Club, vol. 60, p. 508.

1946 Alnus speciipites Wilson and Webster (non the non four pored forms), Amer. Jour. Bot., vol. 33, no. 4, p. 275, fig. 11.

1959 Alnus maritima Macko [non (Marshall) Muhlenberg], Traveaux de la Societe de Science et des Lettres des Wroclaw Seria B., Nr. 96, pl. 19, figs. 6-11.

1962 Alnus pre-cordata Simpson (non the non four pored forms), Roy. Soc. Edin., p. 442, pl. 13, fig. 1.

1962 Alnipollenites Type B Manum, Norsk Polarinstitutt Skrifter nr. 125, p. 62, pl. 16, fig. 9.

1961 Polyvestibulopollenites eminens Takahashi, Kyushu Univ. Publ., Ser. D (Geol.), vol. 2, no. 3, p. 308, pl. 20, figs. 21-34.

1962 Alnus quadrapollenites Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, p. 102, pl. 29, figs. 7-10.

DIAGNOSIS: "Pollen grains typically square in outline with the four pores situated at the angles. Bands of the wall connecting the pores are obvious. The exine

around the pores is not greatly thickened, so that no prominent pores are in evidence. Exine levigate. Size range 25-27μ (Rouse, 1962, p. 202).

REMARKS: Specimens from this study are identical in all features with those described by Rouse. Several species were found without any specimens of the five pored variety, which tends to verify Rouse's subdivision of A. quadrapollenites and A. quinquepollenites on the basis of pore number. There is no doubt in the writer's mind that the four pored segment of A. speciipites Wodehouse is conspecific with A. quadrapollenites Rouse.

AFFINITIES: Rouse (1962, p. 202) states that: "Specimens from the Burrard are almost identical with the modern pollen of Alnus maritima (Marshall) Muhlenberg". Macko (1957) referred similar pollen grains to the extant species A. maritima.

OCCURRENCE AND ABUNDANCE: Although only 18 pollen grains in a count of 4400 were found, a few specimens were recovered from all sections studied. Alnus quadrapollenites makes up about 25 percent of the total Alnus type pollen.

GEOLOGIC RANGE: See discussion following A. quinquepollenites.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 11, figs. 4 & 8	Slide No. Q3-3-12-6	Co-ord. 123.4/59.5
fig. 5		124.1/65.9
fig. 6		124.1/31.2
figs. 7 & 9		120.4/33.7

Alnus quinquepollenites Rouse 1962

Pl. 11, fig. 10-14

1962 Alnus quinquepollenites Rouse, Micropaleontology, vol. 8, no. 2, p. 202, pl. 2, figs. 7 and 8.

? 1931 Alnipollenites versus Potonié, Brennsteine Preuss Geol. Landesanstalt Berlin, Bd. 4, p. 58, pl. 2, figs. 13, 17, 18, 25, 26.

1933 Alnus speciipites Wodehouse (non the non five pored forms), Bull. Torr. Bot. Club, vol. 60, p. 508, fig. 40.

? 1934 *Alnipollenites verus* Potonie, Arb. Inst. Paleob. 4, Taf. 2, fig. 13, 17, 18, 25, 26, Taf. 6, fig. 28.

? 1934 *Alnipollenites verus* Potonie and Venitz, Brennsteine Preuss Geol. Landesanstalt Berlin, Bd. 5, 55-54, p. 25, Taf. 2, fig. 51.

1946 *Alnus speciipites* Wilson and Webster (non the non five pored forms), Amer. Jour. Bot., vol. 33, no. 4, p. 275, fig. 10.

1961 *Alnipollenites eminens* Takahashi (non the non five pored), Kyushu Univ. Publ. Ser. D (Geol.), vol. 2, no. 3, p. 308, pl. 20, figs. 21-34.

1962 *Alnus pre-cordata* Simpson (non the non five pored), Roy. Soc. Edin., p. 442, pl. 13, figs. 2 and 6.

? 1962 *Alnipollenites* Type A Manum, Norsk Polarinstitutt Skrifter Nr. 125, p. 62, pl. 16, figs. 1-4.

? 1962 *Alnipollenites* Type B Manum, Norsk Polarinstitutt Skrifter Nr. 125, p. 62, pl. 16, figs. 5-9.

1962 *Alnus quinquepollenites* Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, p. 102, pl. 29, figs. 7-10.

DIAGNOSIS: "Pollen grains broadly pentagonal in outline with five pores situated at the angles. The pores are distinct, with a prominent thickening of the exine immediately surrounding the pore. Thickened bands between the pores are sometimes present but generally lacking. Size range 20-22μ.(Rouse, 1962, p. 202).

REMARKS: Specimens from this study are undoubtedly conspecific with *A. quinquepollenites* Rouse. However, the specific diagnosis should be modified to include grains ranging from 20-33 microns, and the statement that the arci are generally lacking is misleading. One of the diagnostic features of *Alnus* is the presence of arci. The statement should read "arci are often poorly developed".

AFFINITIES: Grains are undoubtedly related to the extant genus *Alnus*; specific relationships are doubtful as several extant species have pollen of this form.

OCCURRENCE AND ABUNDANCE: Rare, less than 200 observed during this study, and definitely less than one percent of the total pollen assemblage. In a count of 4400 grains from Princeton, B.C., only 8 grains of this type were found. Most abundant in Unit 2. Comprises about 75 percent of the total Alnus pollen.

GEOLOGIC RANGE: Alnus type pollen has been recorded from strata ranging in age from Upper Cretaceous to Recent. There is a suggestion that the number of pores may be of stratigraphic importance. Grains from the Senonian beds recently studied by the writer indicated that 70 percent were six pored, and the remaining 30 percent were five pored.

In their study of Paleocene deposits of Montana, Wilson and Webster (1946, p. 575) state that four to six pored grains were found. The four pored grains were most common, whereas only two, six-pored grains were found. In Eocene deposits four to six pored grains have been reported: (Potonie, 1931; Potonie, 1934; Potonié and Venitz, 1934; Simpson, 1936; Tokunaga, 1958; Wodehouse, 1933). Six pored grains are rare, and were not reported by Hills, 1962; Rouse, 1962.
In this study, a single six pored grain was found at Quilchena. Thompson and Pflug (1953, p. 90) report three to seven (mostly five) pored grains (Polyvestibulopollenites verus) in the middle European Tertiary. They state that these grains are rare in the Alttertiar (Paleocene, Eocene and Lower Oligocene). Erdtman (1943, pp. 68-70) reports that three to six pored grains are found in extant species, but that five-pored grains appear to be most common.

The above comments on the number of pores indicate that if the majority of grains are six pored, a late Cretaceous age is suggested; if four pores predominate then a Paleocene age is implied; whereas a predominance of the five pored types would indicate an Eocene to Recent age.

All reports and the present study where percentage total of the alder pollen is available indicate that they are rare in early Tertiary deposits (Manum, 1962, pl. 21;

Rouse, 1962, p. 191; Thompson and Pflug, 1953, p. 90). This should not be interpreted to mean that they are not locally abundant, but that they are relatively less than in later Tertiary strata. If verified, this may find application in the future as an age indicator.

Genus Carpinus Linnaeus 1753

Carpinus ancipites Wodehouse 1933

Pl. 11, figs. 15-17, Pl. 12, figs. 1-4

1933 Carpinus ancipites Wodehouse, Bull. Torr. Bot. Club, vol. 60, p. 510, fig. 42.

1950 Carpinus ancipites Saulnier, Unpubl. M.Sc. Thesis, Univ. of Mass., p. 38, pl. 3, fig. 3.

1958 Carpinus sp. Tokunaga, Geol. Surv. Japan Rept. no. 181, p. 36, pl. 6, fig. 26.

1962 Carpinus ancipites Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, p. 102, pl. 29, figs, 13, 16, 17.

DIAGNOSIS: "In life apparently oblately flattened, angular in outline; 27.4-44.5μ in diameter. Pores 3 or 4, their apertures elliptical; when 3 meridionally arranged; when 4, on the equator with their major axis converging in pairs; very slightly or not at all protruding, and the exine surrounding them scarcely or not at all thickened; pore pattern as in the Carpinus "type", texture smooth (Wodehouse, 1933, p. 510, fig. 42).

REMARKS: Fourteen grains were measured and the size ranged from 27 to 35 microns, with only two grains less than 30 microns. Two four-pored grains were observed, one at Princeton and the other at Quilchena. Grains of this species are very similar to Momipites coryloides and can be differentiated from it only by the thickened annulus in the latter.

AFFINITIES: Grains of this type are very similar to extant species of both

Carpinus and *Ostrya*. There is a tendency to list grains of this type found in post-Pleistocene deposits as *Ostrya*–*Carpinus* "type". Samoilovitch 1965 assigned similar grains to *Comptonia*. The presence of leaves of *Comptonia* at Princeton and Coalmont suggests that the modern affinities of these grains should be checked.

The relationship of this fossil to *Carpinites dilatus* Agranovskaya should be investigated.

OCCURRENCE AND ABUNDANCE: The stratigraphic range of this species at Princeton is obscured by the difficulty to differentiate it from *Carya veridifluminipites* and *Carya juxtaporipites*. Samples studied from the Coalmont coalfield and the strata at Quilchena suggest that it is restricted to the upper part of the section never found in amounts greater than one percent.

GEOLOGIC RANGE: *Carpinus ancipites* has been reported in strata ranging in age from Paleocene to Eocene.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 11, figs. 15-17	Slide No.	Q3-3-23-12-6	Co-ord.	126.2/57.4
		TS5-1-3-17-1-5		119.7/62
Pl. 12, figs. 1-4		TS5-1-3-17-1-5		119.7/62
		TS5-3-3-17-16-7		122.2/47.3
		TS5-3-3-16-1-2		120.2/44.4

FAMILY FAGACEAE

Genus *Castanea* Tourn. ex Linn. 1735

Castanea sp.

Pl. 12, fig. 5

DIAGNOSIS: Tricolporate, perprolate to prolate. Colpi long, tapering, almost meeting at the poles. Transverse (equatorial) furrow frequently present. Pores distinct and bounded by a thickened rim. Polar: equatorial ratio 1.30 to 1.86, mainly 1.50 to 1.66, average 1.50. Size: polar axis 20-29μ; equatorial axis 13-18μ (12 grains). Exine levigate.

REMARKS: This species can be differentiated from C. minutapollenites Rouse (1957, p. 369, pl. III, figs. 67-68) and Tricolporopollenites castaneoides Takahashi (1961, p. 321, pl. 24, figs. 34-40) by the presence of well-developed pores not present in the latter two species. It can be differentiated from Castanea sp. Tokunaga (1958, p. 38, pl. 6, figs. 10 and 15); C. sativa Potonie (1934, S 61); and C. insleyana Traverse (1955, p. 47, fig. 10, no. 39) by its much larger size. It appears to be larger than Castanea "type" pollen Couper (1965, p. 133, pl. 1, figs. 14A and B). Castanea shiebensis Simpson (1961, p. 463, pl. 19, figs. 10-12) is also very similar to the present species in polar: equatorial index, but is slightly smaller in actual size of both measurements.

This species is very similar to if not identical with Tricolporopollenites cingulum subsp. fuscus (Potonie) Thompson and Pflug (1953, p. 100, Taf. 12, fig. 15-27).

AFFINITIES: Pollen grains of this type closely resemble those of extant genus Castanea. Erdtman (1943, p. 98) states, "It may be difficult or even impossible to decide whether a pollen grain of the Castanopsis type should be referred to Castanopsis or to Castanea....Castanopsis pollen has been encountered in Tertiary deposits". Simpson (1961, p. 463) states that Castanea pollen can be differentiated from Pasania densiflora which are straight sided, whereas the former are elliptical in outline. In addition to the pollen morphology, the presence of leaves of Castanea at Princeton, B.C. (Rice, 1947, p. 29) suggests that the interpretation of this species is correct.

OCCURRENCE AND ABUNDANCE: Present in all samples except Driftwood Creek, McAbee, Tranquille, and Williams Lake. It occurs throughout the section at Princeton and Coalmont. It is more frequently encountered in the upper part of the section. Because of its small size it can easily be overlooked.

GEOLOGIC RANGE: Bolkhovitina (1953, p. 94, pl. 15, figs. 33-40)

described C. vakhrameevii from strata said to be of Lower to Middle Albian age. This assignment must be verified before it can be accepted, because it implies that modern angiosperms can be recognized in what are normally considered pre-angiosperm strata. Couper (1965, p. 133) illustrates an undoubted Castanea "type" pollen from the Upper Cretaceous. Rouse (1957, p. 369) described C. minutapollenites from Upper Cretaceous strata of Western Canada. Although his specimens are clearly tricolpate, neither the description nor the illustration indicates that a pore is present, and the assignment of this grain to Castanea is doubtful. Thompson and Pflug (1953, p. 100) describe several species of the form genus Tricolporopollenites which if they are not Castanea, are some closely allied form, from strata ranging in age from Eocene to Pliocene. Samigulina (In Pokrovskaya and Stel'mak, 1960, p. 496, pl. 2, fig. 2) describes a fossil species C. crenataeformis from the Eocene of Russia. Tokunaga (1958, p. 38, pl. 16, figs. 10 & 15) reports pollen grains resembling those of the extant genus Castanea from Eocene strata of Hokaido. Simpson (1961, p. 463, pl. 19, figs. 10-12) describes a new species of fossil Castanea based on pollen from late Tertiary strata of Western Scotland. From the foregoing discussion it is apparent that Castana-type pollen occur in strata as old as late Cretaceous. It is therefore necessary to base any age assignment according to species. As stated previously, the species herein described is either closely related to or identical with Tricolporopollenites cingulum subsp. fuscus. Thompson and Pflug state that this type of grain is common in the Altertertiar (Eocene to lower Oligocene) and rare in the Metteltertiar (middle Oligocene to middle Miocene). They make no mention of its presence in strata younger than middle Miocene.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 12, fig. 5 Slide No. TS5-3-3-16-1-2 Co-ord. 126.4/55.3

ORDER JUGLANDALES

FAMILY JUGLANDACEAE

Genus Juglanspollenites Raatz 1937

Juglanspollenites sp.

Pl. 12, figs. 6-7

DIAGNOSIS: Polyporate, equatorial outline circular; pores: six, concentrated on a single hemisphere, elongate parallel to the equator, five microns long by two microns wide, with a slightly thickened annulus; exine smooth and about 1 micron thick; size 30 microns.

REMARKS: Assignment to Juglanspollenites is based on the hemispherical distribution of the pores.

AFFINITIES: Members of the Juglandaceae are characterized by a tendency to have the pores concentrated on one hemisphere. The single specimen found can be differentiated from Pterocarya by the pore orientation, which is parallel to the equator rather than perpendicular to it. It differs from Juglans in the tendency for the pores to be close to the equator. It can be differentiated from Carya by its pore character and number. Of the members of the Juglandaceae it most closely resembles Juglans.

OCCURRENCE AND ABUNDANCE: Only a single specimen of this type was found at Coalmont, British Columbia.

GEOLOGIC RANGE: The strata at Coalmont are correlated palynologically with the middle Eocene Allenby Formation.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 12, figs. 6 & 7	Slide No. TS5-3-16-2-3	Co-ord. 116.4/42.5

Carya viridi-fluminipites (Wodehouse 1933) Wilson and Webster 1946

Pl. 12, figs. 8-9

1946 *Carya viridi-fluminipites* (Wodehouse 1933) Wilson and Webster, Amer. Jour. Bot. vol. 33, p. 276, fig. 13.

1933 *Hicoria viridi-fluminipites* Wodehouse, Bull. Torr. Bot. Club vol. 60, p. 503, fig. 29.

1950 *Carya viridi-fluminipites* Saulnier, Unpubl. M.Sc. Thesis, Univ. of Mass., p. 36, pl. 3, fig. 1.

1962 *Carpinus ancipites* Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, pl. 29, fig. 15.

DIAGNOSIS: Oblately flattened and rounded, triangular in outline, 36-39 microns in diameter; pores three, near the equator of the grain circular or slightly elliptical with their long axis directed meridionally, 2.3-3.4 μ long.

REMARKS: The specimens from British Columbia are very similar to those described by Wodehouse. Possibly the only difference is the aspidate character of the pore, which, however, is a character of *Carya*-type pollen. *C. viridi-fluminipites* can be differentiated from *Carpinus* by the non-equatorial position and aspidate character of the pores. *C. viridi-fluminipites* can be differentiated from *C. spackmania* (Traverse, 1955 p. 46, fig. 9, no. 33) by its smaller size. Grains of this type are very similar to Type B. *Triporates* Manum (1962, p. 59, pl. 15, figs. 10-12).

OCCURRENCE AND ABUNDANCE: Rare; occurs at all localities and throughout the section.

GEOLOGIC RANGE: *Carya viridi-fluminipites* has been reported in strata ranging in age from Paleocene (Wilson and Webster, 1946) to middle Eocene (Wodehouse, 1933). The presence of mammal remains in the Allenby Formation indicates a middle Eocene age for these deposits. *Carya* pollen has also been reported

from the Oligocene (?) (Traverse, 1955, p. 46); Miocene (Wolfe, 1962, p. 82); Mio-Pliocene (Mathews, and Rouse, 1963, p. 58); Recent (Harlow and Harrar, 1958, p. 276). Therefore, any account of Carya pollen must be accompanied by a specific diagnosis in order that it have stratigraphic importance.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 12, figs. 8 & 9 Slide No. TS5-3-3-16-1-2 Co-ord. 126.1/57.5

FAMILY JUGLANDACEAE

Genus Carya Nuttall, 1818

Carya juxtaporipites (Wodehouse 1933) Rouse 1962

Pl. 12, fig. 10

1933 Hicoria juxtaporipites Wodehouse, Bull. Torr. Bot. Club, vol. 60, p. 504, fig. 30.

1962 Carya juxtaporipites Rouse, Micropaleontology vol. 8, no. 2, p. 203, pl. 2, fig. 13, 14 and 16.

1962 Carpinus ancipites Hills, non Wodehouse, Unpubl. M.Sc. Thesis, Univ. of British Columbia, Pl. 29, fig. 14.

DIAGNOSIS: "Similar to C. veridi-fluminipites; 31.2 microns in diameter, pores 3, 2.3μ in diameter, not close to the equator and arranged in a triangle. Exine granular" (Wodehouse, 1933, p. 504). Rouse (1962, p. 203) states that the specimens from British Columbia ranged from 23 to 29 microns. Size range therefore from 23 to 31 microns.

REMARKS: Specimens of this species are difficult to differentiate from C. veridi-fluminipites and can only be separated on the basis of slightly smaller size and granular exine.

OCCURRENCE AND ABUNDANCE: Two grains of this type were found at Quilchena.

GEOLOGIC RANGE: To date this species has been reported only from strata of Eocene age.

ORDER JUGLANDALES

FAMILY JUGLANDACEAE

Genus Platycarya Sieb. and Zucc.

? Platycarya sp.

Pl. 12, fig. 11

DIAGNOSIS: Triporate; triangular; pores on the equator, slit like and converging towards the poles, aspidate, sides slightly convex; exine faintly granular to smooth. Crossed by two arcuate folds (collapsed grooves) one on each surface at right angles to each other. Size 23 to 26 microns.

REMARKS: Assignment of this grain to Platcarya is tentative.

OCCURRENCE AND ABUNDANCE: Two grains of this type were found about 50 feet stratigraphically above the coal seam on Collins Gulch.

GEOLOGIC RANGE: Hail and Leopold (1960, p. 260) state that Platycarya is known only from Eocene sediments in the new world. However, the tentative assignment of two grains to this genus must not be construed as evidence for an Eocene age.

ORDER JUGLANDALES

FAMILY JUGLANDACEAE

Genus Pterocarya Kunth 1824

Pterocarya sp.

Pl. 12, figs. 12-15

1962 Pterocarya sp. Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, p. 104, pl. 29, figs. 22-23.

DIAGNOSIS: Grains 5 to 9 pored, predominantly 5 or 6 pored; pores with

slightly thickened annulus, frequently displaced from the equator onto one hemisphere, pores elongate parallel to the equator. Exine levigate to faintly granular. Grains frequently with ridges developed by folding. Size ranges from 26 to 42 microns. The size distribution appears to fall into two groups, one in the 26 to 34 micron range, and another in the 37 to 42 microns, possibly suggesting two natural species. Exine about one micron thick.

REMARKS: This species is similar to P. vermontensis Traverse. It differs from Pterocarya sp. Tokunaga (1958, p. 37) by the larger size of the former. It is very similar to Polyporopollenites polyceras Takahashi in size and ornamentation.

AFFINITIES: Grains of this type are very similar to modern pollen of Pterocarya and can be differentiated from those of Juglans by the hemispherical distribution of pores in the latter.

OCCURRENCE AND ABUNDANCE: Pollen of this type is present at Princeton, Coalmont, Quilchena and on the Nicola Mamit Road locality. It is most common in strata above the Princeton Black Coal Seam, and only two grains were found below the seam. At Coalmont they were recorded only from above the coal seam on Collins Gulch. At Quilchena they also appear above the abandoned coal mine half a mile south of Quilchena. Its presence is very suggestive of the post-coal strata.

GEOLOGIC RANGE: Pollen of Pterocarya-type have been reported from strata ranging in age from lower Eocene, Takahashi (1961); Oligocene (?), Traverse (1955); Miocene, Wolfe (1962); late Miocene - early Pliocene, Mathews and Rouse (1963). To date there has been insufficient work on the genus to state whether or not it will eventually have stratigraphic importance.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 12, figs. 12-15	Slide No. TS5-1-3-17-1-5	Co-ord. 117.2/40.4
	TS5-3-3-16-1-2	124/58.6
	TS5-3-3-16-2-3	115.8/54.8

ORDER MALVALES

FAMILY TILIACEAE

Genus Tilia Linnaeus 1753

Tilia crassipites Wodehouse 1933

Pl. 13, figs. 1-4

1933 Tilia crassipites Wodehouse, Bull. Torr. Bot. Club, vol. 60, p. 515, fig. 48.

1953 ? Intratriporopollenites instructus (Pot and Ven) Thompson and Pflug; Palaeontographica, Abt. B., p. 89, pl. 10, figs. 14-23.

1960 T. crassipites, Hail and Leopold, 1960, U.S.G.S. Prof. Paper 400B, pp. 260-261.

1961 ? Intratriporopollenites ambiguus Takahashi, p. 307, pl. 21, figs. 16-17 (L. Eocene).

1962 T. crassipites Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, p. 104, pl. 29, fig. 24.

DIAGNOSIS: "Grains apparently lens-shaped at least somewhat oblately flattened in life.... Pores three, sunken in deep pits. Exine thick and coarsely reticulate. Size 43.3 x 36.5μ", (Wodehouse, 1933, p. 515, fig. 48).

REMARKS: The specimens from British Columbia range from about 35 to 40 microns. They are rounded-triangular with the pores situated midway between the apices (sinuaperturate). The ornamentation is finely reticulate at the poles, becoming progressively finer-meshed and ultimately coarse-granular at the equator. The lumina of the reticulum at the poles are less than two microns. The exine is distinctly divided into an endexine and an ectexinous layer. The endexine is thickest on the overhanging lip of the pore and thins progressively as it arcs beneath the pore forming the base of the vestibulum. Pore about 2.5 microns wide by about 2.5 microns deep. Exine about 1.0 to 1.5 microns thick.

The specimens from British Columbia can be assigned to T. crassipites with

little doubt. They are also very similar to Intratriporopollenites ambiguus Takahashi and cannot readily be differentiated. The only difference is, that T. crassipites is slightly larger. Tilia crassipites can be differentiated from T. grandipollenites Traverse, (1955, p. 61) by its smaller size, maximum 43 microns as opposed to an average of 49 microns, and its thinner exine, two microns versus four microns in the latter.

AFFINITIES: The affinities of this fossil pollen with Tilia are undoubted. Wodehouse (1933, p. 515) states that there is a marked resemblance between the fossil and the extant species T. americana.

OCCURRENCE AND ABUNDANCE: Extremely rare, only seven grains encountered in a total count of 4400. Present at Princeton and Quilchena, British Columbia.

GEOLOGIC RANGE: To date Tilia pollen has not been reported in strata older than early Eocene. It has been reported from Eocene sediments by Wodehouse, 1933; Hail and Leopold, 1960; Oligocene sediments by Hail and Leopold, 1960; Traverse, 1955; from Miocene sediments by Wolfe, 1962; and Mio-Pliocene sediments by Mathews and Rouse, 1963. Little (1953) recognizes four native species in North America today. Thus the presence of Tilia (macro or micro-fossil) would imply a post-Paleocene age for the sediments. Hail and Leopold (1960, p. 261) state that T. crassipites is known only from rocks ranging in age from early Eocene through Oligocene, but is absent in strata of Paleocene Age. Both reports of Tilia by Wolfe and by Mathews and Rouse are at the generic level only. Mathews and Rouse (1963, pl. 57) state of the early Tertiary strata that: "Although many genera are the same, most species are distinctly different from those of the late Tertiary sedimentary rocks". Whether Tilia falls into this different category is uncertain. It is, however, apparent that precise correlation will have to be based on species determinations and not at the generic level. The probable range of T. crassipites is early Tertiary (Eocene-Oligocene). Specific identity with Intratriporopollenites ambiguus would suggest Eocene.

Tilia-type pollen has a similar stratigraphic range in Europe, (Thompson and

Pflug, 1953); Russia, (Kuprianova, 1960); Japan, (Takahashi, 1961).

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 13, figs. 1-4 Slide No. Q3-3-23-12-6 Co-ord. 110.4/31.8
115/32.5

Tilia vesipites Wodehouse

Not illus.

1933 *Tilia vesipites* Wodehouse, Bull. Torr. Bot. Club, vol. 60, p. 516, fig. 49.

DIAGNOSIS: Triporate; equatorial outline rounded triangular; pores situated midway between the apices (sinuaperturate), exine about two microns thick; ektexine extends as a lip over the edge of the vestibulum; endexine forms base of vestibulum; exine finely reticulate to coarse granular; size about 26 microns.

REMARKS: These grains can be differentiated from *Tilia crassipites* by their smaller size and finer reticulate to granular ornamentation.

AFFINITIES: Undoubtedly *Tilia*. Wodehouse states that this pollen is very similar to the extant species *T. americana*, differing only on its smaller size.

OCCURRENCE AND ABUNDANCE: Rare; only two grains of this type were encountered, one at Princeton and the other at Quilchena.

GEOLOGIC RANGE: Known range Eocene.

Tilia tetraforaminipites Wodehouse, 1933

Pl. 13, figs. 5-6

1933 *Tilia tetraforaminipites* Wodehouse, Bull. Torr. Bot. Club, vol. 60, p. 516, fig. 50.

1962 *Tilia tetraforaminipites* Rouse, Micropaleontology, vol. 8, no. 2, p. 204, pl. 2, fig. 10.

DIAGNOSIS: Tetraporate, typically square in outline with pores situated at the angles. Pores surrounded by a thickened annulus, oval in outline (max. three

microns). Vestibulum not well defined. Ornamentation coarse granular to reticulate with mesh diameter less than two microns. In specimens where the texture is granular, the baculae are arranged in definite linear patterns, which if connected would form the mesh of a reticulum. Size 26 microns (four specimens).

REMARKS: Wodehouse (1933, p. 516) states that this species is similar to *T. vescipites* except that the exine is finely pitted and there are four pores instead of three.

AFFINITIES: Wodehouse (1933, p. 516) suggests that grains of this type resemble *T. americana* except that they have four pores instead of the characteristic three of the latter. Rouse (1962, p. 204) states that there is some question as to the affiliation with *Tilia* and suggests that it may belong with *Comptonia*, *Ulmus*, or *Myriophyllum*. It is noteworthy of note that *Comptonia* macrofossils have been identified from Princeton, Coalmont and the Tranquille beds.

OCCURRENCE AND ABUNDANCE: Rare, not encountered in a total count of 4400 grains from Princeton and Coalmont, British Columbia. Three grains were found in samples from Quilchena and a single grain from Coalmont.

GEOLOGIC RANGE: Known to occur in the middle Eocene Green River Formation (Wodehouse, 1933, p. 516); the Burrard Formation at Third Beach, Vancouver (Rouse, 1962) and the Allenby Formation, Princeton, of middle Eocene age.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 13, figs. 5-6 Slide No. TS5-3-3-16-1-2 Co-ord. 125/57.5

ORDER SALICALES

FAMILY SALICACEAE

Genus Salix Linnaeus 1753

Salix discoloripites Wodehouse 1933

Pl. 13, figs. 7-8

1933 Salix discoloripites Wodehouse, Bull. Torr. Bot. Club, vol. 60, p. 506, figs. 34-35.

1962 Salix discoloripites Rouse, Micropaleontology, vol. 8, no. 2, p. 203, pl. 4, fig. 33.

1962 Salix discoloripites Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, p. 105, pl. 29, fig. 26-27.

1962 Salix sp. Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, p. 106, pl. 29, fig. 28-29.

DIAGNOSIS: Tricolpate and generally more or less deeply three lobed, isodiametric, slightly elongate or oblately flattened, according to the degree of expansion 13.7 - 23.9 microns in diameter. Furrows long and tapering without internal marginal thickenings and without germ pores; exine thick and coarsely reticulate, with the network generally finer towards the margins of the furrows and towards the poles (Wodehouse, 1933, p. 506).

REMARKS: The specimens studied may belong to two distinct species, one of which would be identical to S. discoloripites Wodehouse, the other a very similar species. According to Wodehouse, his species is always coarsely reticulate, whereas in the specimens studied, the ornamentation ranges from coarse granular with a tendency towards reticulation, to clearly reticulate forms. The polar axis ranges from 20 to 35 microns in length.

AFFINITIES: Undoubtedly related to Salix. Wodehouse (p. 506) states that the grains match exactly those of Salix discolor and S. fragilis. There is also a

strong similarity of the coarsely reticulate forms to *S. hookeriana*.

OCCURRENCE AND ABUNDANCE: Rare; but has been identified in all strata studied. Thirty-nine grains of this type were encountered in a total count of 4400.

GEOLOGIC RANGE: Middle Eocene. This species occurs in the Green River Formation of Wyoming (Wodehouse 1933). The Burrard of Vancouver, B.C. (Rouse, 1962), and the Allenby (this study), all of Middle Eocene age.

CLASS ANGIOSPERMOPSIDA - INCERTAE SEDIS

Form - genus *Tricolpites* Cookson 1947 ex Couper 1953

Tricolpites scabratus n. sp.

Pl. 13, figs. 9-10

DIAGNOSIS: Tricolpate; prolate to perprolate when collapsed, equatorial dimension in polar compression equal to polar dimension in equatorial compression; therefore, originally spherical; colpae broad, deep, and extending almost to the poles, exine less than one micron thick and of uniform thickness from colpus to colpus; smooth to faintly reticulate. Size: polar axis 18 to 24 microns long and 13 to 16 microns wide in equatorial compression.

REMARKS: This species can be differentiated from *Acer* sp. (see pl. 13, figs. 11, 12 & 15) by the uniform thickness and scabrate texture of the exine. The specific epithet is in reference to the ornamentation.

AFFINITIES: *Salix* ? Pollen of this type is very similar to *S. sitchensis* in size and ornamentation.

OCCURRENCE AND ABUNDANCE: Pollen of this type was encountered in all sections studied, but was not observed in a total count of 4400 grains.

GEOLOGIC RANGE: Known range middle Eocene.

TYPE LOCALITY: Strata above the coal adit on Collins Gulch at Coalmont,

B.C.

HOLOTYPE: Pl. 13, figs. 9 & 10, Slide No. TS5-3-3-16-2-3, Co-ord. 122/44.9

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 13, figs. 9-10 Slide No. TS5-3-3-16-2-3 Co-ord. 122/44.9

CLASS ANGIOSPERMOPSIDA

ORDER SAPINDALES

FAMILY ACERACEAE

Genus Acer (Tournafort) Linnaeus 1753

Acer tulameenensis n. sp.

Pl. 13, figs. 11, 12 & 15

1962 Acer sp. Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, p. 108, pl. 29, figs. 35-39.

DIAGNOSIS: Tricolpate; sub-prolate to sub-spherical; colpae extending almost to the poles, broad, well-defined. Exine about one micron thick, smooth to fine granular. There is a pronounced thinning of the exine towards the colpae. Size range: polar and equatorial axis 20 to 26 microns. Originally spherical.

REMARKS: This species can be differentiated from A. quilchensis by its smaller size and the inward curve of the colpi resulting in a smaller apocolpium. Two distinct types of Acer samaras have been found at Princeton and McAbee, suggesting that subdivision of the pollen into two species is valid.

AFFINITIES: There is no doubt that pollen of this type belongs to Acer.

OCCURRENCE AND ABUNDANCE: Fifty-seven grains of this species were encountered in a total count of 4400. They occur sparcely throughout the section. Observed at Princeton, Coalmont, Quilchena and Driftwood Creek.

GEOLOGIC RANGE: Known range middle Eocene based on mammal remains in the Allenby Formation at Princeton, British Columbia. Wolfe (1962, p. 84) reports

two species of Acer from the Miocene of Oregon. Therefore, if pollen of this type is to have stratigraphic significance, identification must be at the specific level.

TYPE LOCALITY: Strata above the coal adit on Collins Gulch at Coalmont, B.C.

HOLOTYPE: Pl. 13, figs. 11 & 12, Slide No. TS5-3-3-16-2-3 Co-ord. 124.3 x 40.3

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 13, figs. 11-12 Slide No. TS5-3-16-2-3 Co-ord. 124.3/40.3

<u>Acer</u> <u>quilchensis</u> n. sp.

Pl. 13, figs. 13-14

1962 <u>Acer</u> sp. Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, p. 107, pl. 29, figs. 33-34.

DIAGNOSIS: Tricolpate; prolate; colpae narrow elongate slits extending about three fourths of the distance to the poles; exine about one micron thick, thinning progressively towards the colpae; ornamentation smooth to faintly granulose. Size: polar axis (equatorial compression) 33 to 40 microns, equatorial diameter 26 to 31 microns. In polar compressions the diameter ranges up to 39 microns, indicating that the original grain was spherical.

REMARKS: This species is distinguishable from <u>A</u>. <u>tulameenensis</u> by the larger size and the lack of infolding of the colpae.

AFFINITIES: The thinning of the exine towards the colpae is very similar to the condition found in extant species of <u>Acer</u>. The specific name is from the type locality Quilchena, British Columbia.

OCCURRENCE AND ABUNDANCE: Twenty-six grains of this type were found in a total count of 4400 from the Allenby Formation, a single one at Coalmont, and five at Quilchena.

GEOLOGIC RANGE: Associated fossil mammals in the Allenby Formation at

Princeton, British Columbia, indicate a middle Eocene age for this pollen type. Wolfe (1962, p. 84) states that there are two pollen species of Acer present in Miocene strata of Oregon, but does not describe them, and it is not known whether they are identical with the two species found in this study.

TYPE LOCALITY: Coldwater Beds at Quilchena B.C.

HOLOTYPE: Pl. 13, fig. 13 & 14, Slide No. Q3-23-12-6, Co-ord. 112.3/25.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 13, figs. 13-14 Slide No. Q3-3-23-12-6 Co-ord. 112.3/25

FAMILY HIPPOCASTANACEAE

Genus Aesculus Linnaeus 1753

Aesculus ? sp.

Pl. 13, figs. 16-18

1962 Aesculus sp. Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, p. 108, pl. 29, figs. 40-41.

DIAGNOSIS: Tricolpate; perprolate to prolate, colpae extending almost to the poles, narrow, well defined; colpae membranes covered with coarse granules or coni; exine less than one micron thick, smooth except on the colpae membranes; size: polar dimensions 22 to 31 microns, equatorial diameter 10 to 18 microns.

AFFINITIES: The ornamentation on the colpae membranes indicates affinities with the extant genus Aesculus. However, Erdtman (1952, p. 204) states that similar grains are found both in the Aceraceae (Dipteronia) and Sapindaceae.

OCCURRENCE AND ABUNDANCE: Rare, but identified from all strata studied.

GEOLOGIC RANGE: Middle Eocene.

ORDER ERICALES

FAMILY ERICACEAE

Genus Ericipites Wodehouse 1933

Ericipites sp.

Pl. 14, figs. 1-2

DIAGNOSIS: Daughter cells fused in tetrad; diameter of tetrad about 34 microns, of individual cells about 16 microns; exine smooth to fine granular at 400 power magnification, distinctly reticulate under oil immersion (about 1200 magnification). Three distinct furrows on each grain, each furrow contiguous and continuous with a furrow on the adjacent grain. Furrow length about one third the diameter of the cell. There is no evidence of a germinal pore in the area of contact between adjacent furrows.

REMARKS: This pollen is similar to Ericipites Type C Manum (1962, p. 29) in ornamentation and size. However, Manum does not describe furrows on his specimens. The specimens found in this study are smaller and lack the pore described by Wodehouse.

AFFINITIES: Tetrad fusion is characteristic of the Empetraceae, Ericaceae and several species of the Typhaceae. In the Typhaceae, each cell bears a germ pore, and hence, can be readily differentiated from furrowed forms. The presently described form is similar to Calluna vulgaris (Erdtman, 1943, p. 92) and Andromedia prolifolia (Erdtman, 1943, p. 91). The affinities are uncertain but are either with the Empetraceae or the Ericaceae.

OCCURRENCE AND ABUNDANCE: Pollen of this type was observed in all sections studied, but it is rare. Eighteen grains of this type were encountered in a total count of 4400.

GEOLOGIC RANGE: Pollen grains assignable to Ericipites have been found in strata ranging from Senonian to Recent (Samoilovich and Mchedlischvili 1961, pl. 49,

fig. 17). Species have not been differentiated, and hence it is not known whether the species from the middle Eocene strata of this study are identical to those of later epochs.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 14, figs. 1-2 Slide No. TS5-3-16-1-2 Co-ord. 123/46.8

CLASS ANGIOSPERMOPSIDA

ORDER URTICALES

FAMILY URTICACEAE

Genus *Momipites* Wodehouse 1933

Momipites coryloides Wodehouse 1933

Pl. 14, fig. 3

1933 *Momipites coryloides* Wodehouse, Bull. Torr. Bot. Club, vol. 60, p. 511, fig. 43.

1946 *Momipites coryloides* Wilson and Webster, Am. Jour. Bot., vol. 33, p. 275, fig. 15.

1950 *Momipites coryloides* Saulnier, Unpubl. M.Sc. Thesis, Univ. of Mass., p. 46, pl. 3, fig. 8.

DIAGNOSIS: "Oblately flattened and triangular in outline, 21 - 31.1 in diameter. Pores three, on the equator, with their apertures broadly elliptical and meridionally oriented, only slightly protruding above the surface, and with the exine immediately surrounding them slightly thickened, corresponding to the *Corylus* pattern. Texture smooth." (Wodehouse, 1933, p. 511, fig. 43).

REMARKS: Grains of this type are very similar to those of *Carpinus ancipites*, and can only be differentiated from the latter on the basis of the aspidate pores. Similar forms have been reported from the Eocene of Germany by Kirchheimer (1932) and from the Scottish Tertiary by Simpson (1936, 1962.)

AFFINITIES: Both Wodehouse, and Wilson and Webster indicate that pollen of this type is very similar to the extant genus Momisia.

OCCURRENCE AND ABUNDANCE: Due to the similarity of this species to those of Carpinus ancipites it is sometimes difficult to differentiate the 2, and hence to assess their abundance. Momipites coryloides has been positively identified from all localities, and occurs throughout the section.

GEOLOGIC RANGE: Senonian to Eocene. The writer has observed pollen of this species (less than one percent total pollen) in strata of Senonian age (unpubl.). Wilson and Webster (p. 277) state that 32.2 percent of the total pollen count from the Kolarich coal seam were of this species. Wodehouse (p. 511) states that grains of Momipites coryloides are common in the middle Eocene Green River Formation. In the beds of this study, they constitute less than one percent of the total pollen. The above record suggests that Momipites first appeared in the later Cretaceous, reached their maximum development in the Paleocene or early Eocene or both, and diminished in middle Eocene times. As far as is known, pollen of this type has not been reported in strata younger than Eocene in North America.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta
Pl. 14, fig. 3 Slide No. TS5-1-3-17-3-7 Co-ord. 124/54.7

FAMILY HALERAGIDACEAE

Genus Myriophyllum Ponted. ex. L.

Myriophyllum ambiquipites Wodehouse

Pl. 14, figs. 4-5

1933 Myriophyllum ambiquipites Wodehouse, Bull. Torr. Bot. Club, vol. 60, p. 516, fig. 51.

DIAGNOSIS: Oblately flattened and decidedly angular in outline, 21.6 μ in diameter. Pores four abruptly protruding above the surface of the grain and

surrounded by a thickened ring of the exine, of the Betula pore pattern with apertures slit-shaped and converging in pairs. Exine slightly granular, particularly around the pores, (Wodehouse, 1933, p. 516, fig. 51).

REMARKS: Only a single specimen of this type was found. It is slightly larger than the specimen described by Wodehouse (p. 516), 26 microns as compared to 21.6 microns, but in all other respects is similar to the specimen described by Wodehouse. Wodehouse (1935, p. 445) states that the size of the extant M. spicatum ranges from 23.1 to 33 microns. Therefore, we cannot infer that the size of a species is established on the basis of a single specimen. Further, Wodehouse (1935, p. 445) states that in M. spicatum the pore number ranges from three to five. It is, therefore, possible that M. ambiquipites will eventually be shown to be conspecific with M. pentapollenites described by Rouse (1962) from the Burrard.

This species can be readily differentiated from Tilia tetraforaminipites by pore shape and smooth exine, as opposed to granular to reticulate in the latter. Rouse (1962, p. 204) states that it can be differentiated from M. pentapollenites by the presence of five pores and the larger size range of the latter.

The specimen superficially resembles Zelkova. See Loma and Ricciardi (1961, pl. 13, fig. 9) but is readily distinguishable on the basis of pore shape.

OCCURRENCE AND ABUNDANCE: Only a single specimen was found in Sample Q3 from immediately above coal mine working one-half mile south of Quilchena, British Columbia.

GEOLOGIC RANGE: Probably Eocene. This species was described on the basis of a single specimen recovered from the middle Eocene Green River Formation.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 14, figs. 4-5 Slide No. Q3-23-12-6 Co-ord. 111.8/36.8

CLASS ANGIOSPERMOPSIDA

SUBCLASS DICOTYLEDONIDAE

ORDER CONTORTAE

FAMILY GENTIANACEAE ?

Genus Pistillipollenites Rouse 1962

DIAGNOSIS: "Pollen grains circular to broadly subtriangular in outline. Triporate (? tricolpate), with the three openings generally obscured by club or pistil-shaped elements of ornamentation. The wall is about 2μ thick, with no obvious division into ektexine and endexine; the presence of costae has not been confirmed because no clear view of the pores has been available. Size range 20-30μ " (Rouse, 1962, p. 206).

Pistillipollenites Mcgregorii

Pl. 14, figs. 5-16

1962 Pistillipollenites mcgregorii, Rouse, Micropaleontology, vol. 8, no. 2, p. 206, pl. 1, figs. 8-12.

1949 ?Vesculites problematicus Wilson and Webster, unpubl. M.S.

1950 ?Vesculites problematicus Saulnier, unpubl. M.Sc. Thesis, Univ. of Mass., p. 26, pl. 1, figs. 3-4.

1962 P. mcgregorii, Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, p. 109.

DIAGNOSIS: "As in the description for the genus, with the following additions: the pistil shaped ornaments resemble young mushrooms emerging from the soil, i.e. they are circular to oval in shape....pores (or colpae?), which are hidden between and under the projections....The projections are not generally evenly distributed on the surface of the wall, but tend to be concentrated on one surface. The size range is 20-30μ " (Rouse, 1962, p. 206).

REMARKS: There is no doubt that the studied specimens are conspecific with P. mcgregorii. However, the status of the pores or colpae is open to question. Small

ruptures were observed in a number of grains, but these could not definitely be equated with pores. Light areas surrounding many of the projections could be mistaken for areas of thinning, but this is an optical effect. Specimens from the Interior of British Columbia also show a wider range of ornamentation than those illustrated by Rouse. The projections may be densely packed over the entire surface of the grain, or they may be reduced to as few as 6 or 7; some grains show a parallel arrangement of projections. The relationship to Vesculites problematicus should be investigated.

AFFINITIES: Rouse (1952, p. 206) suggests a possible relationship to the extant genus Rusbyanthus Gilg, from Bolivia.

OCCURRENCE AND ABUNDANCE: Characteristic of the upper portion (Unit 2) of the section. Rare, except at Quilchena (Q3) but present in almost all slides obtained from the upper part of the section. Although Rouse (1962) reports it in association with Azolla primaeva, Pistillipollenites mcgregorii was not found with Azolla spores in this study.

GEOLOGIC RANGE: To date this fossil has been reported only by Rouse (1962) and Hills (1962). At Princeton, British Columbia, it occurs in association with trogosine tillodonts (Russell 1935; Gazin, 1953) of middle Eocene age. Recently, Rouse and Mathews (1961) obtained a K-Ar date of 48 m.y. on a biotite from a tuff intercalated with the sediments at Princeton. In British Columbia P. mcgregorii appears to be restricted to deposits of middle Eocene age. Saulnier states that V. problematicus was first described by Wilson and Webster 1949 from the middle Eocene Green River. He, in turn, has found it in Fort Union Coals of Paleocene age. Therefore, the range of P. mcgregorii may be Paleocene to middle Eocene.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 14, figs. 6-16	Slide No. Q3-3-23-12-6	Co-ord. 125.5/63.5
		126/60.4
		125.9/45.8
		123.9/24.3
		123.4/53
	TS5-3-3-16-2-3	114.5/63.4
	TS5-3-3-16-1-2	125.7/67.7

SUBDIVISION MONOCOTYLEDONIDAE

ORDER NAJADALES

FAMILY POTAMOGETONACEAE

Genus Potamogeton (Tourn.) Linnaeus

Potamogeton hollickipites Wodehouse 1933

Pl. 14, figs. 17-18, Pl. 15, figs. 1-2

1933 Potamogeton hollickipites Wodehouse, Bull. Torr. Bot. Club, vol. 60, p. 496, fig. 21.

1962 Potamogetonaceae Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, p. 110, pl. 29, fig. 47-49.

DIAGNOSIS: "Spheroidal, somewhat ellipsoidal, ovoidal or variously irregular, 16 to 27.4 microns. Exine rather thin and conspicuously reticulate with a coarse network of beaded ridges. Without pores or furrows" (Wodehouse, 1933, p. 496, fig. 21).

REMARKS: The specimens studied are almost identical to those described by Wodehouse, differing only in a slightly larger size range (up to 32 microns) and the presence of an indistinct furrow.

AFFINITIES: Wodehouse (p. 496) states that Potamogeton can be differentiated from Sparganium by the absence of a germ pore in the former. Wodehouse (1935, p. 299) and Erdtman (1943, p. 299) state of the extant species, that there is a single oblong or circular depression on one surface. The presence of such a depression on material from the Allenby Formation, Princeton, indicates a close relationship to Potamogeton.

OCCURRENCE AND ABUNDANCE: Two hundred and seventy-three grains (about six percent) of this type were encountered in a count of 4400 grains from the Allenby Formation at Princeton. They occur throughout the section, and have been found in all deposits studied.

GEOLOGIC RANGE: Pollen of P. hollickipites has been reported from the middle Eocene Green River Formation (Wodehouse, 1933). At Princeton the associated

mammal remains and K-Ar dates indicate a middle Eocene date for these deposits. To date, there are no known reports of Potamogeton from the Oligocene, Miocene or Pliocene. Wodehouse (1935, p. 300) states that the extant species P. natans and P. amplifolius are common throughout the northeastern United States.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 14, figs. 17-18	Slide No. TS5-3-3-16-102	Co-ord. 120.3/43.9
	TS5-3-3-16-2-3	123.9/49.4
Pl. 15, figs. 1-2	TS5-3-3-16-1-2	120.3/43.9
	TS5-3-3-16-2-3	123.9/49.4

CLASS ANGIOSPERMOPSIDA

SUBCLASS MONOCOTYLEDONIDAE

ORDER PRINCIPES

FAMILY PALMACEAE

Genus Sabal Adanson 1763

Sabal granopollenites Rouse 1962

Pl. 15, fig. 3

1962 Sabal granopollenites Rouse, Micropaleontology, vol. 8, no. 2, p. 202, pl. 1, figs. 3-4.

1962 Sabal granopollenites Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, p. 112, pl. 30, fig. 3.

DIAGNOSIS: "Pollen monocolpate, fusiform in outline, coarsely granulate to weakly reticulate. The single colpae is long and narrow, with weak margins. Size range 28 to 32 microns" (Rouse, 1962, p. 202).

REMARKS: Specimens from the thesis area are identical to those described by Rouse. Similar pollen grains have been referred to Palmaepollenites (Potonie, 1951) and Sabalpollenites (Thiergart, 1938).

AFFINITIES: Rouse (p. 202) states that these grains are similar to Sabal palmetto.

OCCURRENCE AND ABUNDANCE: Pollen of this species is rare, but was found at all localities.

GEOLOGIC RANGE: This species occurs in the Burrard Formation (Rouse, 1962) and in the middle Eocene Allenby Formation at Princeton, British Columbia.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 15, fig. 3 Slide No. TS5-3-3-16-2-3 Co-ord. 114/68

ANGIOSPERMOPSIDA - INCERTAE SEDIS

Form-genus Psilodiporites Varma and Rawat, 1963

DIAGNOSIS: Diporate grains with psilate exine (which may sometime appear finely scabrate under high power).

Psilodiporites krempii Varma and Rawat 1963

Pl. 15, figs. 4-7

1963 Psilodiporites krempii Varma and Rawat, Grana Polynologica, vol. 4, p. 132, figs. 8-9.

1962 Diporites sp. Hills, Unpubl. M.Sc. Thesis Univ. of British Columbia, p. 121, pl. 30, fig. 35.

DIAGNOSIS: "Pollen grains 2 porate, isopolar, bilateral, and tapering towards either end, 20.0-26 x 36-49 x ca. 23μ. Pore areas about 8.6-10μ in diameter. Pores have an opening which is not well defined but presumably circular....about 2.9-4.3μ in diameter. Base of the raised structure thickened, whereas the rest of the area is thin and usually of the same color as the general body. Exine smooth, less than 1μ thick. The grains are fragile and provided with numerous, more or less irregular folds"(Varma and Rawat, 1963, p. 132). Size of specimens in this study: 18 to 34 microns by 18 to 39 microns.

REMARKS: The specimens recovered are unquestionably assignable to P. krempii

Varma and Rawat.

AFFINITIES: Diporate grains occur in the Amaryllidaceae, Apocynaceae, Onagraceae, Bromeliaceae, Lilliaceae, Proteaceae, Rafflesiaceae, Urticaceae, Ulmaceae and Saxifragaceae, but the affiliation of Psilodiporites Krempii is unknown.

OCCURRENCE AND ABUNDANCE: Above the Princeton Black Coal Seam and above the coal seam at abandoned mine workings on Collins Gulch at Coalmont. Rare. It did not appear in a total count of 4400 grains.

GEOLOGIC RANGE: Varma and Rawat (1963, p. 138) indicate a lower to middle Eocene range for this species. At Princeton, B.C., it occurs in middle Eocene sediments.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 15, figs. 4-5	Slide No. TS5-3-16-2-3 Princeton, comparison Hills, 1962, M.Sc. Thesis	Co-ord. 120.4/56

Psilodiporites sp.

Not illus.

1962 Diporites sp. Hills, Unpubl. M.Sc. Thesis, Univ. of British Columbia, p. 121, pl. 30, figs. 36-37.

DIAGNOSIS: Biporate, isopolar, 22-32 x 60-65 Microns, fusiform; pores protruding and apparently composed only of the ektexine, set off from the main body by a thickened annulus; thin walled, psilate 1-1.5μ.

REMARKS: Very similar to P. krempii, differing only in the much larger size. The smallest specimen is 22 microns larger than the largest P. krempii.

AFFINITIES: See P. krempii.

OCCURRENCE AND ABUNDANCE: Rare. Did not appear in a total count of 4400 grains.

GEOLOGIC RANGE: Unknown. Mammal remains and K-Ar indicate a middle Eocene age for the Allenby Formation.

Form-genus Tricolporopollenites, Thompson and Pflug 1953.

Tricolporopollenites sp.

Pl. 15, figs. 8-9

DIAGNOSIS: Tricolporate; prolate to subspheroidal; colpi extend about two-thirds the distance to the poles and bear a well-defined pore at the equator; both the colpi and the pore have a well-defined margo; exine smooth to faintly reticulate, about 0.5 microns thick; size 16 to 22 microns in polar dimension and 16 to 20 microns in equatorial diameter.

AFFINITIES: Pollen of this type is very similar to that of Cornus mas in size, shape, ornamentation and pore detail.

OCCURRENCE AND ABUNDANCE: Occurs at Princeton, Coalmont and Quilchena, but is rare at all three localities.

GEOLOGIC RANGE: Uncertain. At Princeton, mammal remains indicate that the strata are of middle Eocene age.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 15, figs. 8-9 Slide No. TS5-2-3-16-7 Co-ord. 116/65.7

Genus: Triporopollenites Thompson and Pflug 1953

Triporopollenites sp.

Pl. 15, figs. 10-12

DIAGNOSIS: Triporate; triangular; pores located dorsally and about five to seven microns from the equator, circular in outline, unthickened; exine about one micron thick. Ornamentation of dense low verrucae one to two microns wide and less than a micron high. Size 36 microns.

REMARKS: Only a single specimen of this type was observed, which is distinctly different from all other triporate grains encountered.

AFFINITIES: Angiospermae.

OCCURRENCE AND ABUNDANCE: The single specimen was found at Coalmont, British Columbia.

GEOLOGIC RANGE: Strata at Coalmont are correlated palynologically with the middle Eocene Allenby Formation at Princeton.

Triporopollenites (Pflug, 1952) ex Thompson and Pflug, 1953

Triporopollenites cf. formosus Takahashi 1961

Pl. 15, fig. 13

1961 Triporopollenites formosus Takahashi, Mem. Faculty of Sc., Kyushi Univ., Ser. D (Geol.), vol. 11, no. 3, p. 302, pl. 19, fig. 43.

DIAGNOSIS: Triporate; triangular; pores situated at the apices of the triangle, about two microns wide and four microns deep, aspidate, appears to bifurcate at the base; exine about 2.5 microns thick at the equator thinning (?) towards the poles, smooth to faintly punctate. Size about 26 microns.

REMARKS: This form is very similar if not identical to T. formosus.

AFFINITIES: The shape and aspidate character of the pores indicate affinities with the Betulaceae.

OCCURRENCE AND ABUNDANCE: Only a single specimen was found at Coalmont.

GEOLOGIC RANGE: The specimens from Japan were recovered from the early Eocene Hooshuyama Formation of Japan. The present study indicates that the strata at Coalmont correlate with the middle Eocene, Allenby Formation at Princeton. Known range lower to middle Eocene.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 15, fig. 13 Slide No. TS5-1-3-17-1-5 Co-ord. 125.8/47.8

OCCURRENCE AND ABUNDANCE: The single specimen [illegible]

[illegible]

STRATIGRAPHIC RANGE: [illegible]

[illegible]

Hypoxylonites (Pflug 1953) ex Potonié [illegible]

[illegible]

(Pl. 21, Fig. 1)

1981 Hypoxylonites [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

OCCURRENCE AND ABUNDANCE: [illegible]

[illegible]

GEOLOGIC RANGE: [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Genus Polycolpites

1953 Polycolpites Couper. New Zealand Geol. Surv. Paleontological Bull. 22, p. 63.

DIAGNOSIS: Free, isopolar, polycolpate, colpi more than six in number, long. Exine psilate to sculptured (Couper, 1953, p. 63).

REMARKS: In a later paper, Couper (1960, p. 63) describes a new species with five or six colpi, and the generic diagnosis should be emended to read, free, isopolar, polycolpate, colpi five or more.

Polycolpites sp.

Pl. 15, figs. 14-15

DIAGNOSIS: Hexacolpate; equatorial outline circular; three well-defined colpae alternating with three poorly-defined colpae; exine smooth, less than 1 micron thick; equatorial diameter about 21 microns.

REMARKS: Only a single specimen of this type was found.

AFFINITIES: Angiospermae. This grain is very similar to many small tricolpate grains of Acer, except that it differs in having three additional poorly developed colpae.

OCCURRENCE AND ABUNDANCE: Rare, only a single specimen found at Coalmont.

GEOLOGIC RANGE: The strata at Coalmont are correlated palynologically with the middle Eocene Allenby Formation at Princeton, British Columbia.

REPOSITORY: Dept. of Geol. Palynological Collections, Univ. of Alberta

Pl. 15, figs. 14-15 Slide No. TS5-3-16-2-3 Co-ord. 118.9/66.3

SELECTED BIBLIOGRAPHY

Abbey, S. and Maxwell, J. A. (1960): Determinations of potassium in micas; Chem. in Canada, vol. 12, pp. 37-41.

Abuzyarova, R. A. (1953): Fossil flora von Takyr sor nach Angaben der Sporen-pollen-analyse; Bot. Shurnal Acad. Nauk. SSR (Bot. 2 Akad. Wiss. UDSSR) 38 (5) In Russian.

_______________(1953): Iskopaemaya flora lakir-sora po dannin sporovopyetselboga analiza; Bot. Shurnal, 38 (5) 742-744.

_______________(1958): Spore and pollen complexes Akmola Indri kothermium suite (Thurgai depression) (In Russian); Akad. Nauk. Kaz. SSR Mater Inst. Fauny Flory Kazakh 2, 149-156, 2 pl.

Ami, H. M. (1904): Notes on the geological horizons indicated by the fossil plants recently determined by Prof. Penhallow from the various localities in British Columbia and the Northwest Territories of Canada; Sum. Rept. Geol. Surv. of Canada, pp. 6-10.

Anderson, R. Y. (1960): Cretaceous-Tertiary palynology, Eastern side of the San Juan Basin, New Mexico; New Mexico State Bureau of Mines and Mineral Resources, Memoir 6.

Armstrong, J. E. (1944): Preliminary map Smithers, British Columbia; Geol. Surv. Canada, Paper 44-23.

Arnold, C. A. (1947): An introduction to paleobotany; New York, McGraw Hill, 433 pp.

____________(1955a): A Tertiary Azolla from British Columbia; Michigan Univ. Mus. Pal. Contr., vol. 12, no. 4, pp. 37-45, 2 pls.

____________(1955b): Tertiary conifers from the Princeton coalfield of British Columbia; Michigan Univ. Mus. Pal. Contr., vol. 12, no. 12, pp. 245-258, 3 pls.

Artamonova, S. V., and Medvedeva, A. M. (1963): Methods of extracting spores and pollen from oils and the water of oil deposits; Intern. Geol. Rev. vol. 5, no. 11, pp. 1510-1511.

Axelrod, D. I. (1949): Eocene and Oligocene Formations in the Western Great Basin (abs.); Geol. Soc. America Bull., vol. 60, pp. 1935-1936.

Averdieck, F. R. (1958): Pollen von Chenopodiaceen-Typ im Floz Frimmersdorf-ein Hinweis auf seine strandnake Entstehung; Fortschr. Geol. Rheinland Westf., vol. 1, pp. 101-112, 2 pls., 1 text fig., 2 tables.

Baker, H. G. (1955): Aperture membranes in studies of pollen morphology and taxonomy; New Phytologist, vol. 54, pp. 350-352.

Baker, J. Van (1919): Over het Voorhomen van Azolla filiculoides in Pleistocene Zoetwaterkleilagen onder Oosterbeek; Verh. Geol. Mijnb. Gen. voor Nederl. en Kolon., Geol. Ser. 4.

Balme, B. E., Churchill, D. M. (1959): Tertiary sediments at Coolgardie, Western Australia; Jour. Roy. Soc. Western Australia, vol. 42, no. 2, pp. 37-43.

Berry, E. W. (1927): Flora of the Esmeralda Formation in western Nevada; U.S. Nat. Mus., vol. 72, pp. 1-15.

Bloom, G. I. (1960): Oligocene de la region comprise entre la Volga et la Vetluga; Soviet Geol., vol. 3, pp. 123-127.

Bolkhovitina, N. A. (1960): Names of fossil pollen and spores in keeping with the international rules of botanic nomenclature; Trans. of Palaeontological Jour., no. 1, pp. 118-127.

Bradley, W. H. (1931): Origin of the microfossils of the oil shales of the Green River Formation of Colorado and Utah; U.S. Geol. Surv. Prof. Paper 168, pp. 1-56.

(1964): Geology of the Green River Formation and associated Eocene rocks in Southwestern Wyoming and adjacent parts of Colorado and Utah; U.S.G.S. Prof. Paper 496A, pp. A1-A86.

Brenner, G. J. (1963): The spores and pollen of the Potomac Group of Maryland; Maryland Dept. Geol. Mines and Water Resources. Bull. 27.

Brown, R. W. (1934): Recognizable species of the Green River flora; U.S. Geol. Surv. Prof. Paper 185-C.

Brown, C. R. (1957): Comments on European Tertiary pollen studies; Micropaleontology, vol. 3, no. 1, pp. 81-82.

Buell, (1946): Size frequency study of fossil pine pollen compared with herbarium preserved pollen; Am. Jour. Bot. vol. 33, pp. 510-516.

Cain, A. (1939): Pollen analysis as a palaeoecological research method; Bot. Rev. vol. 5, pp. 627-654.

Campbell, D. H. (1893): On the development of Azolla filiculoides; Ann. of Bot., vol. 7, pp. 155-187, pl. 7-9.

Camsell, C. (1907): Preliminary report on a part of the Similkameen District, British Columbia; Geol. Surv. Canada, Prelim. Rept. no. 986.

Celet, P., and Delcourt, A. (1960): Les Terrains neogenes de Locride (Grece orientali moyene) leur situation geologique et leur age; Annales de la Societe Geologique du Nord., 80.

Chandler, M. E. J. (1955): The Schizaeaceae of England in early Tertiary times; Brit. Mus. (Nat. Hist.), Bull. Geol., vol. 2, no. 7, pp. 291-314, pls. 32-38.

Chaney, R. W. (1948): The bearing of the living Metasequoia on problems of Tertiary paleobotany; Proc. Nat. Acad. Sci. vol. 34, pp. 503-515.

Chibrikova, E. V. (1963): Conditions of formation of sporepollen complexes and their use for the restoration of the environment of sedimentation and paleogeography; Trans. from Izvestiya USSR Acad. of Sci. Geol. Series, Nr. 12.

Chithaley, S. D. (1951a): Fossil microflora from the Mohgaon Kalan beds of the Madhya Pradesh India; Proc. Nat. Inst. Sci. India, vol. 17, no. 5, pp. 373-383.

______________ (1951b): Further report on the fossil microflora from the Mohgaon Kalan beds of Madhya Pradesh; Proc. 38, Indian Sci. Cong. Bangalore, Pt. 3, pp. 159-160.

______________ (1957): Further report on the fossil microflora from the Mohgaon Kalan beds of Madhya Pradesh; Proc. Nat. Inst. Sci. India P & B 23 (3 & 4) pp. 69-79.

Cockfield, W. E. (1948): Geology and mineral deposits of Nicola map-area, British Columbia; Geol. Surv. Canada Mem. 249.

Cookson, I. C. (1954): The occurrence of an older Tertiary microflora in Western Australia; Aust. Jour. of Sci. vol. 17, no. 1, pp. 37-38.

____________ (1957): On some Australian Tertiary spores and pollen grains that extend the geological and geographical distribution of living genera; Proc. Roy. Soc. Victoria N.S., vol. 69, no. 1, pp. 41-53.

____________ (1959): Fossil pollen grains of Nothofagus from Australia; Proc. Roy. Soc. Victoria N.S., vol. 71, no. 1, pp. 25-30.

Cookson, I. C., and Pike, K. M. (1954): The occurrence of an older Tertiary microflora in Western Australia; Aust. Jour. of Sci., vol. 17, pp. 37-38. Sydney.

Crickmay, C. H., and Pocock, S. A. J. (1963): Cretaceous of Vancouver, British Columbia, Canada; A.A.P.G. Bull. 47, no. 11, pp. 1928-1942.

Dalrymple, G. B. (1963): Potassium-argon dates of some Cenozoic volcanic rocks of the Sierra Nevada, California; Geol. Soc. America Bull., vol. 74, pp. 379-390.

Daly, R. A. (1912): Geology of the North American Cordillera at the forty-ninth parallel; Geol. Surv. Canada, Mem. 38.

Dawson, Sir J. W. (1890): On fossil plants from the Similkameen Valley and other places in the southern interior of British Columbia; Roy. Soc. Canada Trans., vol. 8, no. 4, p. 75.

Dijkstra, S. J. (1961): Some Paleocene megaspores and other small fossils; Mededelingen von de geologische stichting nieuwe series, no. 13, pp. 5-11.

Dilcher, D. L. (1963): Eocene Epiphyllous fungi; Sci. 142, no. 3593, pp. 667-669.

Doktorowicz-Hrebnika, Jr. (1959): Some pollen grains of Taxodiaceae family in the Tertiary brown coal; Kwart. Geol. I. G., vol. 3, pt. 1, pp. 721-736, pt. 2, pp. 1033-1050.

Dorofeev, P. I. (1959): New species of Azolla Lam. in Tertiary floras of the USSR; Bot. Zhurnal SSR, vip. 44, str. 1756-1763.

Dyakowska, J. (1958): On the possibility of determining the pollen of some species of the genus Abies; Acta Biol. Cracoviensia, vol. 1, pp. 57-68.

Erdtman, O. G. E. (1943): An introduction to pollen analysis; Chronica Botanica, Waltham, Mass.

________________ (1947): Suggestions for the classification of fossil and recent pollen grains and spores; Svensk bot. Tidskr., vol. 41, pp. 104-114.

________________ (1952): Pollen morphology and plant taxonomy: angiosperms, an introduction to palynology I; The Cronica Botanica Co., Waltham, Mass.

________________ (1957): Pollen and spore morphology plant taxonomy: Gymnospermae (an introduction to palynology II) Pteridophyta, Bryophyta; Almquist and Wiksell, Stockholm.

________________ (1958): Some suggestions on pollen and spore diagnoses; Jour. of the Palaeontological Soc. of India, vol. 3, pp. 47-52.

Evernden, J. F., Curtis, G. H., Kistler, R. W., and Obradovich, J. (1960): Argon diffusion in glauconite, microcline, sanidine, leucite and phlogopite; American Jour. Sci., vol. 258, pp. 583-604.

Evernden, J. F., and James, G. T. (1964): Potassium-argon dates and the Tertiary floras of North America; American Jour. of Sci., vol. 262, pp. 945-974.

Evernden, J. F., Savage, D. E., Curtis, G. H., and James, G. T. (1964): Potassium-argon dates and the Cenozoic mammalian chronology of North America; American Jour. Sci., vol. 262, pp. 145-198.

Evitt, W. R. (1963): Occurrence of freshwater alga Pediastrum in Cretaceous marine sediments; American Jour. Sci., vol. 261, pp. 890-893.

Faegri, K., and Iversen, J. (1950): Text book of modern pollen analysis; Copenhagen, Ejnur Munksgaard, 168 pp.

Felix, C. J. (1963): Mechanical sample disaggregation in palynology; Micropalaeontology, vol. 9, no. 3, pp. 337-339.

Fernald, M. L. (1950): Gray's manual of botany, eighth edition; American Book Co.

Florschutz, F. (1928): Fossile Azolla in Nederland; Nederl. Kruidk. Archief. Jaarg. Afl. 1, pp. 75-81.

____________ (1935): Over Azolla en de Ouiderdomsbespaling van Interglaciale Zoetwaterafzettingen in Nederland; Geol. en Minjbouw., no. 2.

____________ (1949): Azolla uit het Nederl. Palaeoceen en Pleistoceen; Verh. Geol. Mijnb. Gen. Nederl. en Kol., Geologie 14, pp. 193-197.

Florschutz, F., and Menendez Amor J. (1960): Une Azolla fossile dans les Pyrenees Orientales; Pollen et Spores, vol. 2, no. 2, pp. 285-292.

Foster, F. (1956): The microscopy of fern spores; Amer. Fern Jour., vol. 46, no. 1, pp. 7-14.

Funkhouser, J. W., and Evitt, W. R. (1959): Preparation techniques for acid-insoluble microfossils; Micropaleontology, vol. 5, no. 3, pp. 369-375.

Funnel, B. M. (1965): The Tertiary period. In the Phanerozoic time scale, a symposium; Quart. Jour. Geol. Soc. London, vol. 120S.

Gazin, C. L. (1952): The lower Eocene Knight Formation of western Wyoming and its mammalian faunas; Smithsonian Mus. Misc. Colln. vol. 117, no. 18, 82 p.

____________ (1953): The Tillodontia an early Tertiary order of mammals; Smith. Miss. Coll., vol. 121, no. 10, 110 pp., 38 figs., 16 pls.

____________ (1955): A review of the Upper Eocene Artiodactyla of North America; Smith. Misc. Coll., vol. 128, no. 8.

____________ (1957): A skull of the Bridger middle Eocene Creodont Patriofelis ulta Leidy; Smith. Misc. Coll., vol. 134, no. 8.

____________ (1959): Palaeontological exploration and dating of early Tertiary deposits in basins adjacent to the Uinta Mountain; Intermountain Assoc. Pet. Geol. Guidebook to Geol. of the Wasatch and Uinta Mountain Transition Area, 10th Ann. Field Conf., p. 133-135.

Gignoux, M. (1955): Stratigraphic geology; W. H. Freeman and Co.

Graham, A. (1962): The role of fungal spores in palynology; Jour. of Paleontology, vol. 36, no. 1, pp. 60-68.

Gray, J. (1960): Temperate pollen genera in the Eocene (Claiborne flora) Alabama; Sci., vol. 132, pp. 808-910.

Hail, W. J., Jr. and Leopold, E. B. (1960): Paleocene and Eocene Age of the Coalmont Formation North Park Colorado; Geol. Surv. Paper 400B, pp. 260-261.

Harris, W. F. (1955): A manual of spores of the New Zealand Pteridophyta; N.Z. Dept. Sci. Ind. Res. Bull., 116, pp. 1-186.

Hills, L. V. (1962): Glaciation, stratigraphy, structure and micropaleobotany of the Princeton Coalfield, British Columbia; Unpubl. M.Sc. Thesis, Univ. of British Columbia, 141 pp., 30 pls.

Hills, L. V. and Weiner, N. (1965): Azolla geneseana, n. sp., and revision of Azolla primaeva; Micropaleontology, vol. 11, no. 2, pp. 255-261.

Jentys-Szafer, J. (1928): La structure des membranes du pollen de Corylus de Myrica et especes europeenes de Betula, et leur determination a l'etat-fossile; Bull. Intern. Acad. Polonaise Sci. Let., Ser. B, pp. 75-125.

Jones, E. L. (1961): Environmental significance of Palynomorphs from the Lower Eocene sediments of Arkansas; Sci. vol. 134, p. 1366.

Jones, E. L. (1961): Plant microfossils of the laminated sediments of the Lower Eocene Wilcox Group in south central Arkansas; Unpubl. Ph.D. Thesis, Univ. of Oklahoma, Geol., 126 pp., 9 pls.

Kedves, M. (1961): Etudes palynologiques, dans le Bassin de Dorog - 11; Pollen et Spores, vol. 3, no. 1, pp. 101-154.

__________ (1963): Stratigraphie palynologique des couches Eocene de Hongrie; Pollen et Spores, vol. 5, no. 1, pp. 149-160.

__________ (1964a): Sporomorphes nouveaux des couches Eocenes de Hongrie; Pollen et Spores, vol. 6, no. 1, pp. 195-202.

__________ (1964b): Presence de couches paleocenes en Hongrie d'apres les resultats des etudes palynologiques; Pollen et Spores, vol. 6, no. 1, pp. 203-209.

Krutsch, W. (1957): Sporen and pollengruppen aus der Oberkreide und dem Tertiar Mittel europas und ihre stratigraphische Verteilung; Angewandte Geologie Zeitschr., vol. 3, no. 11-12, pp. 509-548, pls. 1-16.

Krutsch, W. (1959): Mikropalaontologische (sporen palaontologische) Untersuchungen in der Braunkohle des Geiseltales; Geologie, vol. 8, Beiheft 21-22, pp. 1-425, 49 pls., 38 text figs.

Kryshtofovich, A. N. (1929): Evolution of the Tertiary flora in Asia; New Phytologist, vol. 28, pp. 303-312.

__________________ (1935): A final link between the Tertiary of Asia and Europe; New Phytologist, vol. 34, pp. 339-344.

Kulp, J. L. (1961): Geologic time-scale; Sci., vol. 133, no. 3459, pp. 1105-1114.

Kuprianova, L. A. (1960): Palynological data contributing to the history of Liquidambar; Pollen et Spores, vol. 2, no. 1, pp. 71-88.

Kuyl, O. S., Muller, J., Waterbalk, H. T. (1955): The application of palynology to oil geology with reference to Western Venezeula; Geologic en Minjbouw, N.S., vol. 17, no. 3, pp. 49-76, pls. 1-4, text-figs. 1-7.

Lee, H. W. (1964): A modified method of coal maceration and a simple technique for slide preparation; Micropaleontology, vol. 10, no. 4, pp. 486-490.

Leopold, E. B. (1956): Pollen size frequency in New England species of the genus Betula; Grana Palynologica N.S., vol. 1, pp. 140-147.

Little, E. L., Jr. (1953): Check list of native and naturalized trees of the United States (including Alaska); Agr. Handbook 41, U.S. Dept. Agr.

Lona, F., and Ricciardi, E. (1961): Reperti Pollenologici nei depositi Pleistocenici del bacino lacrustre del Mercuri (Italia Meridionale, Region Lucano-Calabra (1); Pollen et Spores, vol. 3, no. 1, pp. 85-100.

Macko, S. (1954): Lower Miocene pollen flora from the valley of Klodnica near Gliwice (Upper Silesia); Comptes rendus de la Societe des Sciences et des Lettres de Wroclaw, vol. 9, pp. 89-.

Macko, S. (1959): Pollen grains and spores from Miocene brown coals in Lower Silicia I; Soc. Sci. Lettres Wroclaw Trav., Ser. B., No. 96, pp. 108, pl. 1-67.

Madler, K. (1954): Azolla aus dem Quartar und Tertiar so wie ihre Bedeutung fur die taxionomie alterer sporen; Geol. Jahrb., 70, pp. 143-158.

Manum, S. (1962): Studies in the Tertiary flora of Spitsbergen, with notes on Tertiary floras of Ellesmere Island, Greenland and Iceland; a palynological investigation; Norsk Polarinstitutt Skrifter Nr. 125.

Marsh, O. E. (1876): Principal characters of the Tillodontia; Amer. Jour. Sci., 3rd Ser., 11, pp. 249-252.

Mathews, W. H., and Rouse, G. E. (1963): Late Tertiary volcanic rocks and plant bearing deposits in British Columbia; Geol. Soc. America Bull., vol. 74, pp. 55-60.

Martin, P. S., and Gray, J. (1962): Pollen analysis and the Cenozoic; Sci., vol. 135, no. 3524, pp. 103-111.

McGrew, P. O. (1951): Tertiary stratigraphy and paleontology of South-central Wyoming; Wyoming Geol. Assoc. Guidebook, 6th Ann. Field Conf. South-Central Wyoming, pp. 54-57.

______________ (1959): The Geology and paleontology of the Elk Mountain and Tabernacle Butte area, Wyoming; Bull. Amer. Mus. Nat. Hist., vol. 117, pp. 121-176.

McGrew, P. O., and Berman, J. E. (1955): Geology of the Tabernacle Butte area, Sublette County, Wyoming; Wyoming Geol. Assoc. Guidebook, 10th Ann. Field Conf., Green River Basin, pp. 108-111.

McGrew, P. O., and Roehler, H. W., (1960): Correlation of Tertiary units in southwestern Wyoming; Wyoming Geol. Assoc. Guidebook, 15th Ann. Field Conf., Overthrust Belt of Southwestern Wyoming and Adj. Areas, 158 pp.

Miner, E. L. (1935): Paleobotanical examinations of Cretaceous and Tertiary coals: Pt. I Cretaceous coals from Greenland; Pt. II Tertiary coals from Montana; Amer. Mid. Nat., vol. 16, pp. 385-625.

Morris, W. J. (1954): An Eocene fauna from the Cathedral Bluffs tongue of the Washakie Basin, Wyoming; Jour. Paneontology, vol. 28, pp. 195-203.

Nagappa, Yedatore (1957): Further occurrences of Botryococcus in Western Pakistan; Micropaleontology, vol. 3, no. 1, p. 83.

Norem, W. L. (1955): Pollen spores, and other organic microfossils from the Eocene of Venezeula; Micropaleontology, vol. 1, no. 3, pp. 261-268.

Pastiels, A. (1948): Contributions a l'etude des microfossiles de l'Eocene belge; Mem. Mus. Roy. Hist. Nat. Belg. 109, pp. 1-77.

Penhallow, D. P. (1903): Notes on Tertiary plants; Roy. Soc. Canada, Trans., vol. 9, no. 4, p. 36.

Penhallow, D. P. (1907): A report on fossil plants from the International Boundary survey for 1902-05 collected by Dr. R. A. Daly; Roy. Soc. Canada Trans., sec. IV, pp. 287-334.

______________ (1908): A report on Tertiary plants of British Columbia, collected by L. M. Lambe in 1906, together with a discussion of previously recorded Tertiary floras; Canada Dept. of Mines Geol. Surv. No. 1013.

Peterman, Z. E. (1962): Precambrian basement of Saskatchewan and Manitoba; Ph.D. Thesis, Dept. of Geol. Univ. of Alberta, Edmonton.

Pocock, S. A. J. (1962): Microfloral analysis and age determination of strata at the Jurassic Cretaceous boundary in the Western Canadian Plains; Palaeontographica, Bd. III Abt. B, pp. 1-94, 15 pls.

Potonie, R. (1931): Pollenformen aus Tertiaren Braunkohlen; Jahrb. Preuss. Geol. Landesanstalt (Berlin), vol. 52, pp. 1-7.

__________ (1956): Synopsis der Gattungen der Sporae dispersae I. Sporites; Beih. Geol. Jb., Hannover, Heft 23, pp. 1-103, pls. 1-11.

__________ (1958): Synopsis der Gattungen der Sporae dispersae II. Sporites (Nachtrage), Saccites, Aletes, Praecolpates, Monocolpates; Beih. Geol. Jb., Hannover, Heft. 31, pp. 1-114, pls. 1-11.

__________ (1960): Synopsis der Gattungen der Sporae dispersae III. Nachtrage Sporites, Fortsetzung Pollenites Mit Generalregister zu Teil I-III; Beih. Geol. Jb., Hannover, Heft 39, pp. 1-189, pls. 1-9.

Potonie, R., Thompson, P. W., and Thiergart, F. (1950): Zur Nomenklatur und Klassifikation der neogenen Sporomorphae (Pollen und Sporen); Geol. Jahrb., 65, pp. 35-70.

Potonie, R., and Venitz, H., (1934): Zur mikrobotanik des miocanen Humbodils der Niederrheinschen Bucht; Arb. Inst. Paleobot., Petrogr., Brennsteine 4, pp. 25-125.

Pflug, H. D. (1953): Zur Entstehung und Entwicklung des Angiospermiden Pollens in der Erdgeschichte; Palaeontographica, Abt. B, Bd. 95, Liefg. 4-6, S60-171, Taf. 15-25, Abb. 1-10, 2 tab.

Radforth, N. W. and Rouse, G. E. (1954): The classification of recently discovered Cretaceous plant microfossils of potential importance to the stratigraphy of western Canadian coals; Can. Jour. Bot., vol. 32, pp. 187-201.

____________________________ (1956): Floral transgressions of major geological time zones; Trans. Roy. Soc. Canada, 3rd Ser., Sec. V, vol. 50.

Rao, H. S. (1935): The structure and life history of <u>Azolla</u> <u>pinnata</u> R. Brown with remarks on the fossil history of the Hydropterideae; Proc. Ind. Acad. Sci., vol. 2, no. 2, pp. 175-200, pls. 13-22.

Reid, E. M., and Chandler, M. E. J. (1926): The Bembridge flora; In Cat. Cainozoic Plants in the Dept. of Geol. vol. 1, London, Brit. Mus. Nat. Hist.

Rice, H. M. A. (1947): Geology and mineral deposits of Princeton map-area, B.C.; Geol. Surv. Canada Mem. 243.

_____ (1957): Fossil Bibionidae (Diptera) from British Columbia; Geol. Surv. Canada Bull. 55.

Romanowicz, I. (1962): Research on systematic reference of Myricaceae and some Betulaceae pollen grains occurring in different Tertiary stages; Poland Biuletyn Instytut Geologiczny 162, Tom 5, pp. 194-226.

Romer, A. S. (1945): Vertebrate paleontology; Univ. of Chicago Press, Chicago.

Rouse, G. E. (1957): The application of a new nomenclatural approach to Upper Cretaceous plant microfossils from Western Canada; Can. Jour. Bot., vol. 35, no. 3, pp. 349-375, 3 pls.

___________(1959): Plant microfossils from the Kootenay coal measures strata of British Columbia; Microplaeontology, vol. 5, no. 3, pp. 303-324.

___________(1962): Plant microfossils from the Burrard Formation of Western British Columbia; Micropaleontology, vol. 8, no. 2, pp. 187-218, pls. 1-5.

Rouse, G. E., and Mathews, W. H. (1961): Radioactive dating of Tertiary plant-bearing deposits; Sci., vol. 133, no. 3458, pp. 1079-1080.

Russell, L. S. (1935): A Middle Eocene mammal from British Columbia; Amer. Jour. Sci., vol. 29, pp. 54-55.

_____ (1958): Mollusca from the Tertiary of Princeton, British Columbia; Bull. 147, Nat. Mus. Canada, pp. 84-95.

Sahni, B., and Rao, H. S. (1934): The silicified flora of the Deccan Intertrappean Series. Pt. IV. Azolla intertrappea, sp. nov.; Proc. 21st Ind. Sci. Cong. pp. 26-27.

______________________ (1943): A silicified flora from the intertrappean cherts round Sausar in the Deccan; Proc. Nat. Acad. Sci. India, vol. 13, no. 1, pp. 36-75.

Sarmiento, R. (1957): Microfossil zonation of the Mancos Group; Bull. AAPG, vol. 41, pp. 1683-1693.

Saulnier, H. S. (1950): The paleopalynology of the (Paleocene) Ft. Union coals of Red Ridge, Montana; M.Sc. Thesis, Univ. of Mass., 62 pp., 5 pls. 13 figs.

Scudder, S. H. (1895): The Tertiary Hemiptera of British Columbia; Contr. to Canadian Paleontology, vol. II, pp. 1-56, pl. 1-3.

Selling, O. H. (1946): Studies in Hawaiian pollen statistics; Part II, the pollens of the Hawaiian Phanerogams; Bernice P. Bishop Mus., Spec. Publ., no. 38, 430 pp.

Shafiqullah, M. (1963): Geochronology of Cretaceous-Tertiary boundary, Alberta, Canada; M.Sc. Thesis, Univ. of Alberta, Edmonton.

Shaw, W. S. (1952a): The Princeton Coalfield, British Columbia; Geol. Surv. Canada Paper 52-12.

___________(1952b): The Tulameen Coalfield, British Columbia; Geol. Surv. Canada Paper 52-19.

Simpson, G. G. (1933): Glossary and correlation charts of North American Tertiary mammal-bearing formations; Bull. Amer. Mus. Nat. Hist., vol. 67, art. 3, pp. 79-121.

Simpson, J. B. (1936): Fossil pollen in Scottish Tertiary coals; Proc. Roy. Soc. Edin. vol. 56, pp. 90-118, 3 pls.

___________(1961): The Tertiary pollen-flora of Mull and Ardnamurchan; Trans. Roy. Soc. Edin. vol. 64, no. 16, pp. 421-468.

Singh, C. (1964): Microflora of the Lower Cretaceous Mannville Group, East Central Alberta; Res. Coun. of Alberta Bull. 15, 239 pp.

Snell, W. H., and Dick, E. A. (1957): A glossary of mycology; Harvard Univ. Press, Cambridge, Mass.

Spielholtz, G., Thomas, L. A., and Diehl, H. (1962): Isolation of spores by wet oxidation; Micropaleontology, vol. 8, no. 1, pp. 109-110.

Stachurska, A. (1959): The morphology of pollen grains of Pterocarya hupensis; Skan Acta Soc. Bot. Pol; vol. 28, no. 2, pp. 315-317.

Stirton, R. A. (1959): Time, life, and man, the fossil record; John Wiley and Sons Inc., New York.

Svenson, H. K. (1944): The New World species of Azolla; Amer. Fern Jour., vol. 34, no. 3, pp. 69-84.

Takahashi, K. (1961): Pollen und sporen des Westjapanischen Alttertiars and Miozans (I. Teil); Mem. of the Fac. of Sci., Kyushu Univ., Ser. D. Geol., vol. XI, no. 2, pp. 155-255.

Takahashi, K. (1961): Pollen und sporen des Westjapanischen Alttertiars und Miozans, II Teil; Mem. of the Fac. of Sci., Kyushu Univ. Ser. D. Geol., vol. 9, no. 3, pp. 279-345.

Terasmae, J. (1955): On the spore morphology of some Sphagnum species; The Cryologist, vol. 53, no. 4.

Thiergart, F. (1937): Die pollenflora der Niederlausitzer Braunkohle, besonders im profil der Grube Marga bei Senftenberg; Kahrb. Preuss Geol. Landesanst., vol. 58.

Thiergart, F. (1938): Die pollenflora der Niederlaustzer Braunkohle, besonders im profil der Grube Marga bei Senftenberg; Jahrb. Preuss Geol. Landesanst. f. Bd. 58, S. 282-351, Taf. 22-31.

__________ (1940): Die Mikropalaontologie als pollenanalyse in dienst der Braunkohle-forschung; Brennstoff-Geologie, Stuttgart.

__________ (1949): Der stratigraphische Wert mesozoischer Pollen und Sporen; Palaeontographica, vol. 89, pt. B, pp. 1-33.

__________ (1953): Uber einige Sporen und Pollen der Perutzer Schichten (Bohmen); Palaeontographica, vol. 95, pt. B, pp. 53-59.

Thompson and Pflug (1953): Pollen and Sporen des mitteleuropaischen Tertiars; Palaeontographica, Bd. 94, Pt. B, pp. 1-138, 15 pls., 1 table.

Tokunaga, S. (1958): Palynological study on Japanese coal. II. Pollen stratigraphical investigations in the coalfields, Middle Hokkaido; Geol. Surv. Japan, Rept. No. 181.

Traverse, A. (1955): Occurrence of the oil forming alga in lignites and other Tertiary sediments; Micropaleontology, vol. 1, no. 4, pp. 343-349.

Trela, J. (1928): Zur morphologie der Pollen korner der einheimischen Tilia Arten; Bull. Intern. Acad. Polonaise Sci. Let. Ser. B, pp. 45-54.

Tschudy, R. H. (1957): Pollen and spore formulae, a suggestion; Micropaleontology, vol. 3, no. 3, p. 277-280.

Uneo, J. (1951): Morphology of pollen of Metasequoia Sciadopitys, and Taiwania; Jour. Inst. Palyt. Osaka City, Univ., Ser. D, vol. 2, pp. 22-26.

Vagvolgyi, A. (1963): Palynology of the type McMurray Formation; Unpubl. M.Sc. Thesis, Univ. of Alberta, 133 pp., 14 pls.

Van Campo-Duplan, M. (1951): Recherches sur la phylogenie des Taxodiacees d'apres leurs grains de pollen; Travaux du Laboratoire Forrestier de Toulouse, t. 11, 1st sect., vol. IV, art. 11.

________________ (1953): Recherches sur la Phylogenie des Cupressacees d'apres leur grains de pollen; Travaux de Laboratoire Forestier de Toulouse, t. 11, 1st sect., vol. IV, art. 3.

Van Der Hammen, T. (1956a): A palynological systematic nomenclature; Bol. Geol. Colombia, vol. 4, nos. 2-3, pp. 63-101.

Van Der Hammen, T. (1956b): Description of some genera and species of fossil pollen and spores; Bol. Geol. Colombia, vol. 4, nos. 2-3, pp. 111-117.

Varma, C. P., and Rawat, M. S. (1963): A note on some diporate grains recovered from Tertiary horizons of India and their potential marker value; Grana Palynologica, vol. 4, no. 1, pp. 130-139.

West, R. G. (1953): The occurrence of Azolla in British Interglacial deposits; New Phyt., vol. 52, pp. 267-273.

Wilmarth, M. G. (1925): The geologic time classification of the United States Geological Survey compared with other classifications; United States Geol. Surv. Bull. 769, 138 pp.

Wilson, L. R. (1956): Composite micropaleontology and its application to Tertiary and near-Recent stratigraphy; Micropaleontology, vol. 2, no. 1, pp. 1-6.

Wilson, L. R., and Webster, R. M. (1946): Plant microfossils from a Ft. Union coal of Montana; Amer. Jour. Bot., vol. 33, no. 4, pp. 271-278, 2 pls. 18 text figs.

______________________________ (1949): The fossil plant and animal microorganisms of two Texas oil wells; The Carter Oil Co. Res. Div., Unpubl.

Wodehouse, R. P. (1933): Tertiary pollen; II. The oil shales of the Green River Formation; Torrey Bot. Club Bull., vol. 60, pp. 497-524.

_______________ (1935): Pollen grains, McGraw Hill Book Co., New York.

Wolfe, J. A. (1962): A Miocene pollen sequence from the Cascade Range of Northern Oregon; U.S. Geol. Surv. Prof. Paper 450-C, pp. C81-C84.

Wolfe, J. A., and Barghoorn, E. S. (1960): Generic change in Tertiary floras in relation to age; Amer. Jour. Sci. Bradley vol. 258A, pp. 388-399.

Zaklinskaya, E. D. (1960): The significance of pollen of the Angiospermae for the stratigraphy of the Upper Cretaceous and Paleogene (Russian; Eng. Trans. by A.T.S. (No. RJ2823) Dokl. Nauk. SSSR, 133 (2) 431-434.

ADDITIONAL REFERENCES CITED

Aldrich, L. T., and Nier, A. O. (1948): Argon 40 in potassium minerals; Phys. Rev., vol. 74, p. 876.

Baadsgaard, H., and Dodson, M. H. (1964): Potassium-argon ages of sedimentary and pyroclastic rocks; the Phanerozoic time scale; Geol. Soc. London, vol. 120S, pp. 119-127.

Baadsgaard, H., Lipson, J., Folinsbee, R. E. (1961): The leakage of radiogenic argon from sanidine; Geochim et. Cosmochim Acta, vol. 25, pp. 147-157.

Clarke, R. T. (1965): Fungal spores from Vermejo Formation coal beds (upper Cretaceous) of Central Colorado; The Mountain Geologist, vol. 2, no. 2, pp. 85-93.

Damon, P. E., and Kulp, J. L. (1958): Excess helium and argon in beryl and other minerals; Amer. Mineralogist, vol. 43, pp. 433-459.

Folinsbee, R. E., Baadsgaard, H., and Lipson, J. (1960): Potassium-argon time scale; Internat. Geol. Cong., 21st Norden, pt. 3, pp. 7-17.

________________________________ (1961): Potassium-argon dates of Upper Cretaceous ash falls, Alberta, Canada; Ann. New York Acad. Sci., vol. 91, pp. 352-359.

Folinsbee, R. E., Baadsgaard, H., and Cumming, G. S. (1962): Dating of volcanic ash beds (bentonites) by the K-Ar method; Nuclear Geophysics Nat. Acad. Sci., N.R.C. Publ. 1075, pp. 70-82.

Goldich, S. S., Nier, A. O., Baadsgaard, H., Hoffman, J. H., and Krueger, H. W. (1961): The Precambrian geology and geochronology of Minnesota; Minn. Geol. Surv. Bull. 41, 193 pp.

Graham, A. (1963): Systematic revision of the Sucker Creek and Trout Creek Miocene floras of southwestern Oregon; Amer. Jour. Bot., vol. 50, no. 9, pp. 921-936.

Hamilton, E. I., Dodson, M. H., and Snelling, N. J. (1962): The application of physical and chemical methods to geochronology; Intern. Jour. Applied Radiation and Isotopes, vol. 13, pp. 587-610.

Hanson, G. (1924): Driftwood Creek map-area, B. C.; Geol. Surv. Canada, Summ. Rept., 1924, Pt. A, pp. 19-37.

Hart, S. R. (1961a): Mineral ages and metamorphism, conference on geochronology of rock systems; Ann. N.Y. Acad. Sci., vol. 91, pp. 192-197.

__________ (1961b): The use of hornblendes and pyroxenes for K-Ar dating; Jour. Geophys. Res., vol. 66, no. 9, pp. 2995-3001.

Lovering, J. F., and Richards, J. R. (1964): Potassium-argon age study of possible lower-crust and upper-mantle inclusions in deep seated intrusions; Jour. Geophys. Res., vol. 69, no. 22, pp. 4895-4901.

Lowdon, J. A. (1960): Age determinations by the Geological Survey of Canada, Rept. 1, isotope ages; Geol. Surv. Canada, Paper 61-17.

Mathews, W. H. (1963): Thirteen potassium-argon dates of Cenozoic volcanic rocks from British Columbia; Univ. of British Columbia Dept. of Geol. Rept. No. 2.

Rankama, K. (1950): Isotope Geology; Pergamon Press, 535 pp.

Samoilovitch, S. R., and Mchedlischivili, N. D. (1961): Pollen spores of western Siberia, Jurassic to Paleocene; Transac. of the all Union Petroleum Sci. Res. Geol. Surv. Inst., vol. 177, pp. 1-657, pls. 1-84 and 1-65.

Schaeffer, O. A., Stoenner, R. W., and Bassett, W. A. (1961): Dating of Tertiary volcanic rocks by the potassium argon method; Ann. N.Y. Acad. Sci., vol. 91, Art. 2, pp. 317-

Steiger, R. H. (1964): Dating of orogenic phases in the central Alps by K-Ar ages of hornblende; Jour. Geophys. Res. vol. 69, no. 24, pp. 5407-5421.

Taylor, R. S., Mathews, W. H., Kupsch, W. O. (1965): Tertiary; In Geol. Hist. of Western Canada A.S.P.G. Spec. Publ.

APPENDIX A

RADIOMETRIC SAMPLE DESCRIPTION

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SAMPLE: AK 625

FIELD NO: Sunday Summit SSV.3.

K MINERAL: Andesine.

SOURCE MATERIAL: Hornblende andesite.

LOCATION: 49° 13' 30" N 120° 33' W. Sunday Summit on the Hope-Princeton Highway about 24 miles south of Princeton, British Columbia. Road cut outcrop of map unit 17 Rice, 1947, Geol. Surv. Canada Mem. 243 (see Fig. 3).

STRATIGRAPHIC POSITION: Upper part of the Lower Volcanic beds (Shaw, 1952) which underlies the Allenby Formation in the Princeton Coalfield.

TREATMENT: See flow chart Fig. 2.

PETROGRAPHIC DATA: Clear, unaltered, euhedral, minus 100 plus 200 mesh, commonly zoned crystals. Composition An_{45} - An_{55} determined by extinction perpendicular to 010. Mineral Associates: Hornblende (AK 626) and devitrified volcanic glass.

REMARKS: Minus 100 mesh size was used because the material below this size was free of adhering glass.

SAMPLE: AK 626

FIELD NO: Sunday Summit SSV.3.

K MINERAL: Oxyhornblende.

SOURCE MATERIAL: Hornblende Andesite.

LOCATION: 49° 13' 30" N 120° 33' W. Sunday Summit on the Hope-Princeton Highway about 24 miles south of Princeton, British Columbia. Road cut outcrop of map unit 17, Rice, 1947, Geol. Surv. Canada Mem. 243.

LOCATION: Same as AK 625.

STRATIGRAPHIC POSITION: Same as AK 625.

SEPARATION TREATMENT: See flow chart Fig. 2.

PETROGRAPHIC DATA: Size -80 + 200 mesh, dark brown to black, clear, unaltered. Mineral associates are plagioclase (AK 625) and volcanic glass.

SAMPLE: AK 627

FIELD NO: Sunday Summit SSV.4.

K MINERAL: Oxyhornblende

SOURCE MATERIAL: Hornblende andesite.

LOCATION: 49° 13' 20" N 120° 33' W. At Sunday Summit about 25 miles south of Princeton, British Columbia, on the Hope-Princeton Highway. Southernmost road cut exposure of map unit 17, Rice, 1947, Geol. Surv. of Canada Mem. 243 (see Fig. 3).

STRATIGRAPHIC POSITION: Upper (?) part of the Lower Volcanic beds, Shaw, 1952, which is the unit underlying Allenby Formation sediments in the Princeton Coalfield. The exact stratigraphic position is difficult to determine because of poor exposures and absence of marker beds within the formation. The outcrop where the sample was collected consists of volcanic breccias, tuffs and interbedded sediments. These strata are tentatively correlated with the upper part of the Lower Volcanic beds, which are known to have interbedded sediment in the upper 100 to 200 feet of the unit. Sediments are uncommon in the lower part.

SEPARATION TECHNIQUE: See flow chart Fig. 2.

PETROGRAPHIC DATA: Size minus 80 plus 200, clear unaltered, dark red brown. Mineral associates are altered plagioclase and devitrified volcanic glass.

SAMPLE: AK 629

FIELD NO: McAbee No. 2.

MINERAL: Andesine An_{40}.

SOURCE MATERIAL: Bentonitic Ash.

LOCATION: 50° 48' N 120° 10' W. One-half mile north of the Cache Creek-Kamloops Highway and two miles west of the point where Battle Creek crosses the highway. (see Fig. 4).

STRATIGRAPHIC POSITION: Sediments interbedded with lava flows belonging to the Kamloops Group.

SEPARATION TECHNIQUE: See flow chart Fig. 2.

PETROGRAPHIC DATA: Size minus 200 plus 270 mesh, clear unaltered plagioclase with no adhering glass. Albite twinning common. Composition An_{40} - An_{45} determined by extinction perpendicular to 010. Associated minerals are biotite (AK 628), green hornblende and volcanic glass.

SAMPLE: AK 630

FIELD NO: Quilchena Bentonite.

MINERAL: Sanidine.

SOURCE MATERIAL: Bentonite.

LOCATION: 50° 8' N 120° 29' W. Twenty-foot thick bed of bentonite exposed in a coal exploration trench on the east slopes of Quilchena Creek one and a quarter to one and a half miles south of Quilchena, British Columbia. (see Fig. 5.)

STRATIGRAPHIC POSITION: Same as AK 631.

SEPARATION TECHNIQUE: See Flow Chart 2.

PETROGRAPHIC DATA: Size minus 200 plus 270 mesh; some grains have a coating of glass which gives them a dull appearance. Mineral associates, biotite (insufficient for a K-Ar run), green hornblende, quartz, and volcanic glass shards.

SAMPLE: AK 631

FIELD NO: Quilchena Bentonite.

MINERAL: Glass shards.

SOURCE MATERIAL: Bentonite.

LOCATION: 50° 8' N 120° 29' W. Twenty foot thick bed of bentonite exposed in a coal exploration trench on the east slopes of Quilchena Creek, one and a quarter to one and a half miles south of Quilchena, British Columbia (see Fig. 5).

STRATIGRAPHIC POSITION: Associated with Tertiary strata containing coal. Palynologically the coal seam is correlated with the Princeton Black Coal Seam and the seam on Collins Gulch, Coalmont. Exact stratigraphic position of the bentonite uncertain, but within 20 feet of the coal seam.

SEPARATION TECHNIQUE: See Flow Chart Fig. 2.

PETROGRAPHIC DATA: Size minus 200 plus 270 mesh. Shards are generally clear and unaltered, but do have minor amounts of adhering clay. Associated minerals are sanidine (AK 630) biotite, hornblende and quartz.

SAMPLE: AK 632

FIELD NO: PRINCETON BIOTITE RHYOLITE P.B.R.I.

MINERAL: Biotite.

SOURCE MATERIAL: White to creamy white-weathering lava flow.

LOCATION: 49° 24' N 120° 32' W. First outcrop of Tertiary volcanics on the abandoned Copper Mountain Railroad about three miles south of Allenby, British Columbia, (see Fig. 3).

STRATIGRAPHIC POSITION: The lava flow rests unconformably on rocks of the Triassic Nicola Group and is overlain by a calculated 500-600 feet of volcanic flows. The uppermost of these flows are interbedded with sediments of the Allenby Formation.

SEPARATION TECHNIQUE: See Flow Chart Fig. 2.

PETROGRAPHIC DATA: Biotite: size minus 80 plus 200 mesh; dark brown to black; unaltered, and contains inclusions of apatite. Mineral associates are zoned plagioclase (An_{45} to An_{55}, AK 633) volcanic glass, and minor amounts of oxyhornblende. The feldspar composition, the presence of oxyhornblende, and the absence of quartz indicates that this lava is an andesite and not a rhyolite as determined in the field.

SAMPLE: AK 633

FIELD NO: Princeton Biotite Rhyolite, P.B.R.1.

MINERAL: Andesine (high andesine to low labradorite).

SOURCE MATERIAL: White to creamy white-weathering lava.

LOCATION: Same as AK 632.

STRATIGRAPHIC POSITION: Same as AK 632.

SEPARATION TECHNIQUE: See Flow Chart Fig. 2.

PETROGRAPHIC DATA: Size minus 80 plus 200 mesh. Crystals, zoned, commonly untwinned, unaltered minor amounts of adhering glass. The composition ranges from An_{45} to An_{55} and was determined by extinction perpendicular to 010. Biotite (AK 632), oxyhornblende, and volcanic glass are the associated minerals.

SAMPLE: AK 634

FIELD NO: South Fork of Sunday Creek.

MINERAL: Sanidine.

SOURCE MATERIAL: Lapilli tuff. Composed of pyroclasts of dark-colored hornblende andesite up to five centimeters enclosed in a light grey weathering sanidine rich matrix. The andesite fragments are derived from earlier flows.

LOCATION: 49° 14' N 120° 34' W. Two-hundred feet south of the south fork of Sunday Creek on the Hope-Princeton Highway about 20 miles south of Princeton,

British Columbia (see Fig. 3). Roadcut outcrop.

STRATIGRAPHIC POSITION: Interpreted by Rice (1947) as part of the Allenby Formation. I interpret the interbedded volcanic detritus and sediments at this point to indicate either a correlation with the upper part of the Lower Volcanic beds, (Shaw 1952) or more probably with a horizon similar to the interbedded volcanics and sediments exposed on the Tulameen River 3 miles west of Princeton, British Columbia. Shaw (1952) interpreted the lava flows and interbedded sediments on the Tulameen as being post-Allenby Formation. However, Hills (1962, M.Sc. Thesis) showed that they belonged to either the basal part of the Allenby Formation or were transitional between the Lower Volcanic beds and the Allenby Formation.

SEPARATION TECHNIQUE: See Flow Chart Fig. 2.

PETROGRAPHIC DATA: Sanidine: size minus 80 plus 200 mesh; clear, unaltered with minor amounts of adhering clay. Quartz was the only other mineral identified in the matrix.

<u>SAMPLE</u>: AK 635

FIELD NO: South Fork of Sunday Creek.

MINERAL: Sanidine. Same as AK 634.

SOURCE MATERIAL:

LOCATION: Same as AK 634.

STRATIGRAPHIC POSITION: Same as AK 634.

SEPARATION TECHNIQUE: See Flow Chart, Fig. 2.

PETROGRAPHIC DATA: Size minus 10, plus 80 mesh. Very little adhering clay, clear, unaltered. The sample was handpicked. Quartz only associated mineral. This is from the same tuff as AK 634, but was selected for its coarseness.

SAMPLE: AK 636

FIELD NO: McAbee No. I.

MINERAL: Andesine.

SOURCE MATERIAL: Bentonite ash.

LOCATION: 50° 48' N 120° 10'W. About two miles west of where Battle Creek crosses the Cache Creek-Kamloops Highway and about 1/2 miles north of the highway (see Fig. 4).

STRATIGRAPHIC POSITION: About 100 feet of sediments interbedded with lava flows of the Kamloops Group. Exact stratigraphic position unknown.

SEPARATION TECHNIQUE: See Flow Chart Fig. 2.

PETROGRAPHIC DATA: Andesine: size minus 100 plus 200 mesh; clear; unaltered; many untwinned. The composition, An_{25}-An_{35} was determined by extinction perpendicular to 010. Sanidine (AK 638) biotite (AK 637), green hornblende, and glass shards are the mineral associates.

SAMPLE: AK 637

FIELD NO: McAbee No. 1.

MINERAL: Biotite.

SOURCE MATERIAL: Bentonitic ash.

LOCATION: Same as AK 636.

STRATIGRAPHIC POSITION: Same as AK 636.

SEPARATION TECHNIQUE: See Flow Chart Fig. 2.

PETROGRAPHIC DATA: Biotite: size minus 80 plus 200 mesh; dark brown to black; unaltered; euhedral grains with inclusions of apatite. Sample contains about 10 percent green hornblende. Mineral associates are Sanidine (AK 638), andesine (AK 636) and green hornblende.

SAMPLE: AK 638

FIELD NO: McAbee No. 1.

MINERAL: Sanidine.

SOURCE MATERIAL: Bentonitic ash.

LOCATION: Same as AK 636.

STRATIGRAPHIC POSITION: Same as AK 636.

SEPARATION TECHNIQUE: See Flow Chart Fig. 2.

PETROGRAPHIC DATA: Sanidine: size minus 200 plus 270 mesh; grains clear, unaltered euhedral, with minor amounts of clay or volcanic glass coating. Biotite (AK 637), green hornblende, andesine (high oligoclase - low andesine, An_{25} - An_{35}), and volcanic glass are the mineral associates.

SAMPLE: AK 640

FIELD NO: Tranquille Ash.

MINERAL: Oligoclase (An_{20} - An_{30}).

SOURCE MATERIAL: Bentonitic ash.

LOCATION: 50° 44' N 120° 33'W. This bentonitic ash bed is well exposed in the first gully east of Battle Bluff on the north shore of Kamloops Lake, British Columbia (See Fig. 6).

STRATIGRAPHIC POSITION: Ten feet above the base of Tranquille beds (Type Locality).

SEPARATION TECHNIQUE: See Flow Chart Fig. 2.

PETROGRAPHIC DATA: Oligoclase: size minus 100 plus 200 mesh; grains clear, unaltered, and twinned by the albite and carlsbad-albite law. Composition determined by extinction perpendicular to 010 and by the Carlsbad-albite method. Sanidine (AK 641), biotite (AK 642), quartz and volcanic glass shards are the associated minerals.

SAMPLE: AK 641

FIELD NO: Tranquille Ash.

MINERAL: Sanidine.

SOURCE MATERIAL: Bentonitic ash.

LOCATION: Same as AK 640.

STRATIGRAPHIC POSITION: Same as AK 640.

SEPARATION TECHNIQUE: See Flow Sheet Fig. 2.

PETROGRAPHIC DATA: Size minus 80 plus 200 mesh. Sanidine grains clear, unaltered, euhedral, with less than one percent of adhering glass.

OPTICAL PROPERTIES: Low 2B, estimated 15 to 20°, optically negative, low negative relief. The biotite (AK 642), quartz, glass shards and oligoclase (AK 640) are the associated minerals.

SAMPLE: AK 642

FIELD NO: Tranquille Ash.

MINERAL: Biotite.

SOURCE: Bentonitic Ash.

LOCATION: Same as AK 640.

STRATIGRAPHIC POSITION: Same as AK 640.

SEPARATION TECHNIQUE: See Flow Chart Fig. 2.

PETROGRAPHIC DATA: Biotite: size minus 80 plus 200 mesh, grains euhedral, brown, unaltered, and contain apatite inclusions. Less than one percent impurities. Sanidine (AK 641), oligoclase (AK 640), quartz and volcanic glass shards are the mineral associates.

SAMPLE: AK 643

FIELD NO: Collins Gulch Bentonite.

MINERAL: Biotite.

SOURCE MATERIAL: Bentonite.

LOCATION: 49° 46' 30" N 120° 45' W. On Collins Gulch, about six miles southwest of Coalmont, British Columbia. (See Fig. 7).

STRATIGRAPHIC POSITION: Four feet stratigraphically below the coal seam exposed at the old mine workings on Collins Gulch. Palynologically the coal seam is correlated with the Princeton Black Coal Seam.

SEPARATION TECHNIQUE: See Flow Chart Fig. 2.

PETROGRAPHIC DATA: Biotite: size minus 80 plus 200 mesh, grains euhedral, brown to black in color, with numerous inclusions of apatite. Andesine (AK 644), and quartz are the associated minerals.

SAMPLE: AK 645

FIELD NO: Driftwood Creek Bentonite.

MINERAL: Sanidine.

LOCATION: 54° 50' N 127° 1' 30" W. On Driftwood Creek seven miles northeast of Smithers, British Columbia. The locality is on the south side of the creek, about midway between the first two bridges crossing the creek when leaving Smithers. The locality well known to local residents as the Driftwood Creek plant locality (See Fig. 8).

STRATIGRAPHIC POSITION: Palynologically, the strata belong to the floral zone which underlies the Princeton Black Coal Seam and the coal seam on Collins Gulch, Coalmont, British Columbia.

SEPARATION TECHNIQUE: See Flow Chart Fig. 2.

PETROGRAPHIC DATA: Sanidine: size minus 80 plus 200, clear, unaltered

and euhedral. Angular chert grains make up about 50 percent of the sample. The chert contammant could not be removed by either the specific gravity method or by means of the magnetic separator. The associated minerals in the bentonite were euhedral quartz grains, chert, and minor amounts of pre-existing volcanic debris.

SAMPLE: AK 656

FIELD NO: Tranquille Ash.

MINERAL: Biotite.

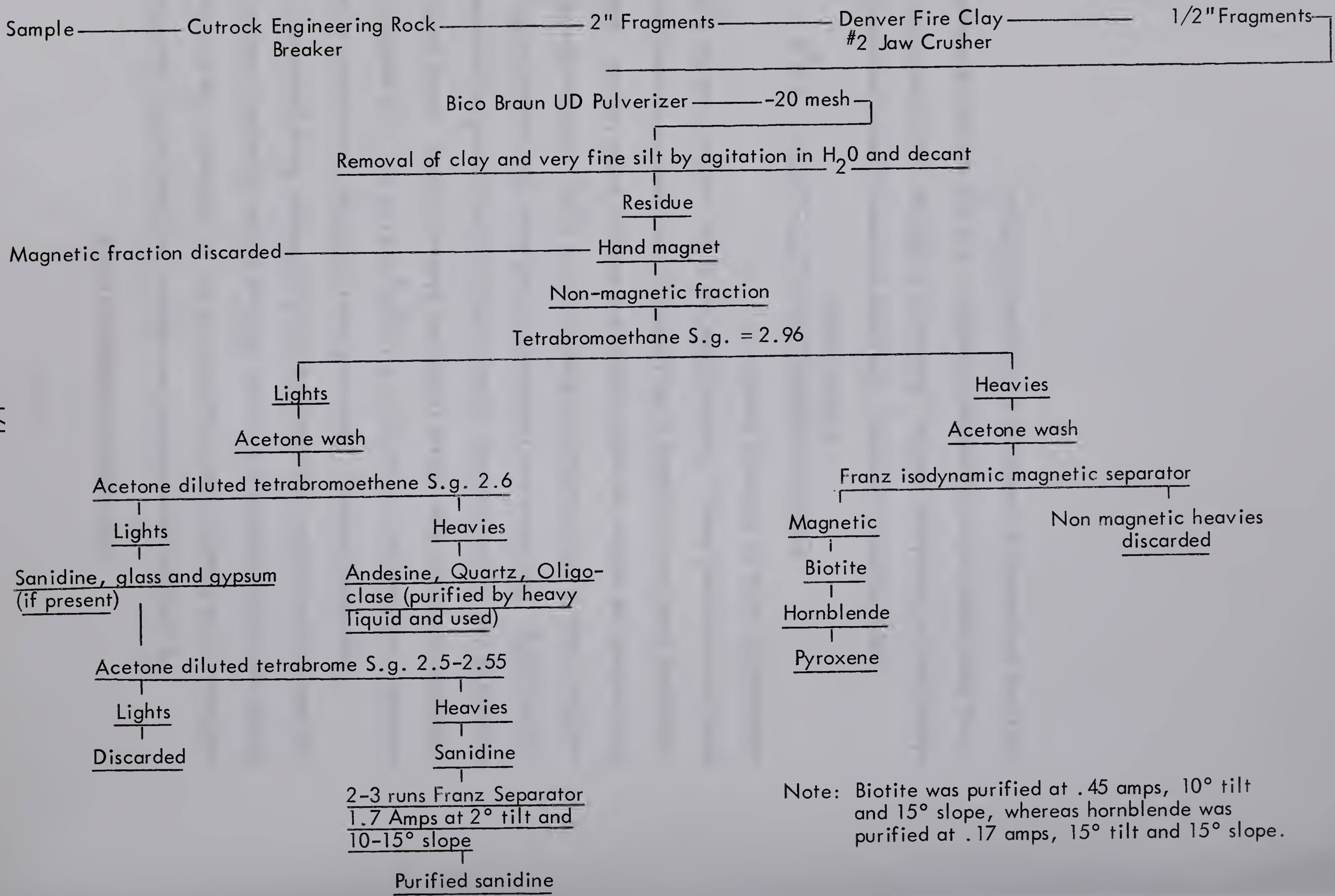
SOURCE MATERIAL: Bentonitic ash.

LOCATION: Same as AK 640.

STRATIGRAPHIC POSITION: Same as AK 640 (see Fig. 6).

SEPARATION TECHNIQUE: See Flow Chart Fig. 2.

PETROGRAPHIC DATA: Biotite: size minus 40 plus 80 mesh, grains euhedral, brown, unaltered and contain small intergrowths of apatite. Sample AK 642 is the finer fraction of this same biotite. Sanidine (AK 641), oligoclase (AK 640), quartz, and volcanic glass are the mineral associates.



Note: Biotite was purified at .45 amps, 10° tilt and 15° slope, whereas hornblende was purified at .17 amps, 15° tilt and 15° slope.

POTASSIUM DETERMINATIONS

The potassium determinations were done in the Geochemistry Laboratory of the University of Alberta under the guidance of Mr. A. Stelmach. The gravimetric method was used for minerals with greater than one percent potassium, whereas minerals with less than one percent were analyzed on a Perkin-Elmer flame photometer.

Gravimetric Method: Samples of about 0.2500 gm. were placed in platinum crucibles, and dissolved in three ml. of 1:1 H_2SO_4 and five ml. of 52 percent HF acid, evaporated to dryness, then ignited (Abbey and Maxwell, 1960). Initial ignition was followed by two to three leachings in water which removed most of the potassium as soluble K_2SO_4. The residue was transferred to filter paper then returned to the platinum crucible, where it was retreated with three ml. of 1:1 H_2SO_4, dried and ignited. After this treatment the residue was again leached and added to initial leaches. Sodium tetraphenol boron was then added to the leachings, and potassium was precipitated as potassium tetraphenol boron. The precipitate was dried, weighed, and the K_2O content calculated by using the following formula:

$$\frac{\text{potassium tetraphenol boron} \times 100 \times .1314}{\text{original sample}} = \% \ K_2O$$

Flame Photometric Method: The flame photometric method was used for all plagioclase and hornblende samples. Samples of 0.5000 gm. were dissolved and leached in the same manner as for the gravimetric method. The K_2O content was determined on the flame photometer by comparison with standard solutions.

Argon Analysis:

Radiogenic Ar^{40} was isolated from potassium bearing minerals by the flux-fusion method (Goldich et al., 1961). A sample of the mineral being dated was fused with a NaOH flux and the gas released was allowed to mix with a known quantity of Ar^{38} (spike) and is then purified. The argon is trapped on charcoal cooled by liquid nitrogen and was then analyzed in the mass spectometer. The mass spectometer measures the abundance ratios of Ar^{40}, Ar^{38} and Ar^{36} and records the data on a strip chart. Since the argon determinations are made by dilution with a known quantity of Ar^{40}, Ar^{38} and Ar^{36}; any contaminating air argon (Air argon 99.6 Ar^{40}, Ar^{38} 0.06, Ar^{36} 0.34) may be determined and eliminated. A correction for any residual argon present was eliminated by obtaining before each run a "residual blank" which was subtracted from the total readings for the run.

The volume of radiogenic Ar^{40} was calculated as follows:

$$Ar^{40}\ \text{CC STP/gm} = \frac{\text{CC STP } Ar^{38}\ \text{(spike)}}{\text{gm sample} \times Ar^{38}/Ar^{40}}$$

This was converted to ppm by multiplying the volume of Ar^{40} present by a factor of 1.7846.

Argon samples were run on both the static and dynamic technique. Age calculations were based primarily on the static technique.

All the argon extraction and mass spectrometer work was done by Dr. H. Baadsgaard.

PLATE 1

Figs. 1-2	Pluraecellaesporites A; Note the detoid septa and perforation. Mag. 1 and 2 x 500.
Figs. 3-4	Pluraecellaesporites B; General view. Mag. x 500.
Figs. 5-10	Phragmosporites quilchenii N. sp.; 5 - paratype; 6-8 - holotype, note hylum; 9-10 - paratype. Mag. 5, 6 and 10 x 500, 7, 8 and 9 x 1000.
Figs. 11-13	Phragmosporites sp.; note deltoid septa. Mag. 11 and 13 x 500, 12 x 1200.
Fig. 14	Diadosporites obovatus N. sp.; holotype. Mag. x 1200.
Figs. 15-16	Designate W29 Rouse 1962; 15 - spore detail. Mag. 15 x 1200, 16 x 500.
Figs. 17-18	Inapertisporites elongatus Rouse; 17 - note flattening and perforations; 18 - note terminal flattening. Mag. 17 x 1200, 18 x 500.

PLATE 1

PLATE 2

Figs. 1-3	Osmundacidites cf. elongatus Rouse; 1 - high focus; 2 - ornamentation base; 3 - general view. Mag. 1 and 2 x 1200, 3 x 500.
Figs. 4-6	Osmundacidites cf. primarius Wolff; 4 - general view; 5 and 6 - details of papillae. Mag. 4 x 500, 5 and 6 x 1200.

PLATE 2

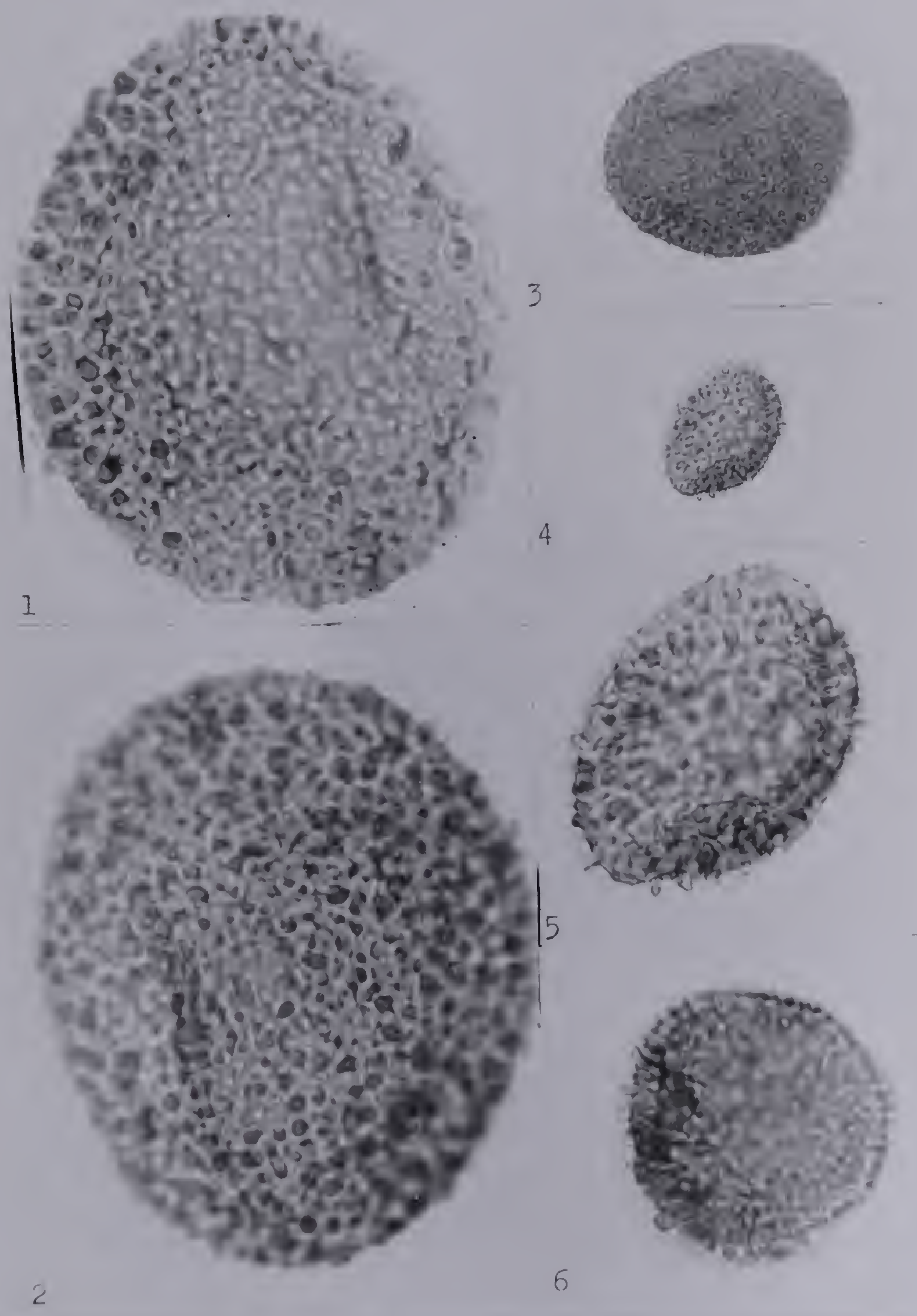


PLATE 3

Fig. 1	Laevigatosporites gracilis Wilson and Webster; general view. Max. x 500.
Fig. 2	Laevigatosporites ovatus Wilson and Webster; general view. Mag. x 500.
Figs. 3-7	Anemia poolensis Chandler; 3 - note the collapsing of spore; 4 and 5 - general view, note margo; 6 - collapsed spore resembling Triplanospora; 7 - note the bifurcate tip of lasurae. Mag. all x 500.
Figs. 8-12	Azolla primaeva (Penhallow) Arnold; 8 - microspore; 9 - massulae; 10 - massula fragment with typical and abberant flukes; 11 - abberant flukes; 12 - typical fluke. Mag. 8-10 x 500, 11 and 12, x 1000.

PLATE 3

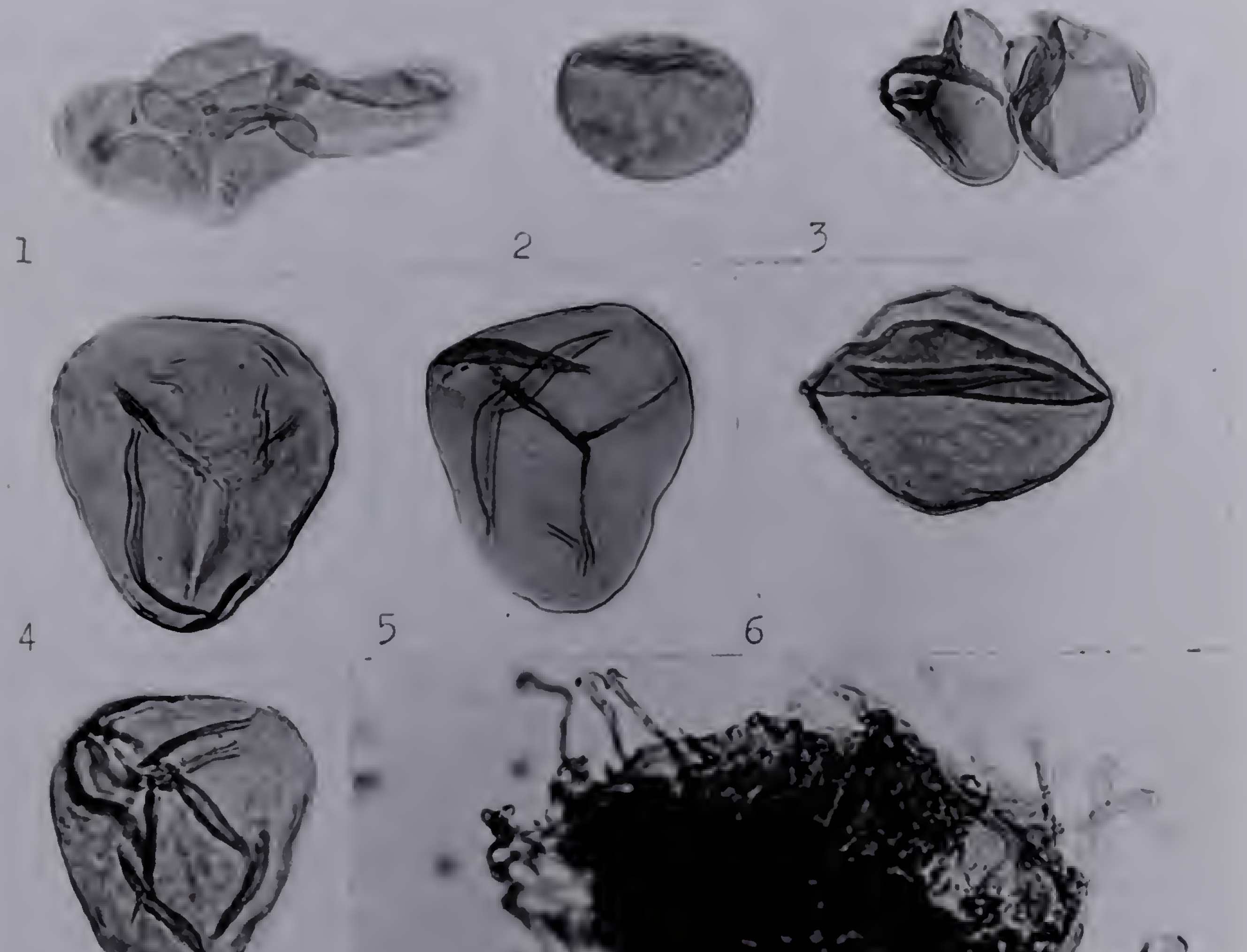
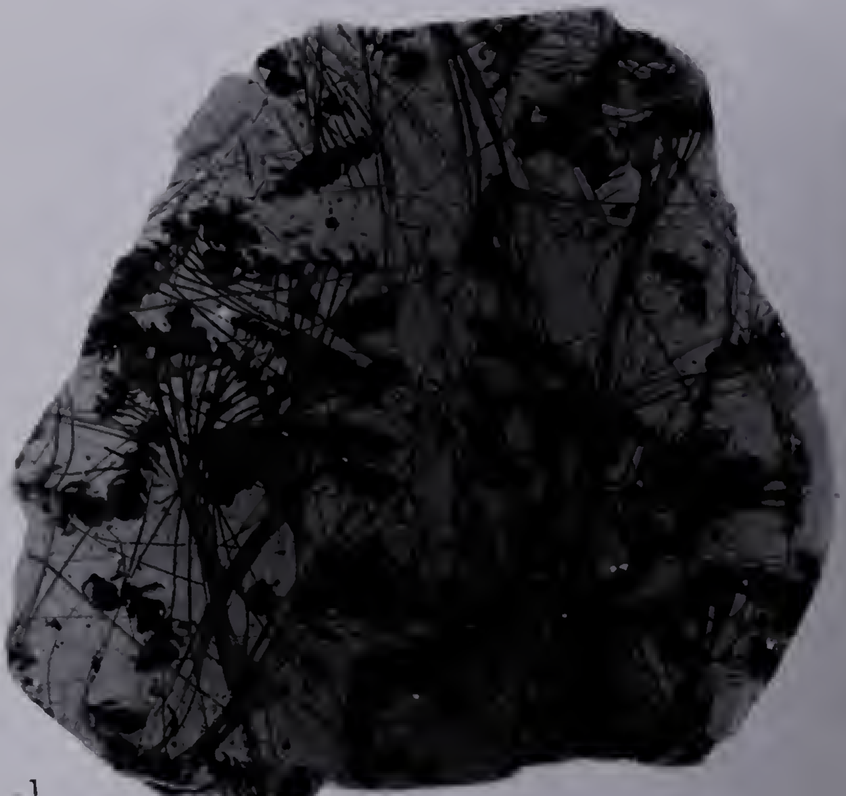


PLATE 4

<u>Azolla</u> <u>primaeva</u> (Penhallow) Arnold;

Fig. 1 and 3	General view of vegetative remains from Asp (China) Creek, near Princeton, British Columbia. Ca xl.
Fig. 2	Megaspores. Note the relationship of the three in the center of the photograph. x 10
Fig. 4	Microsporangia. Note the clustering along the main axis and the polygonal pattern indicating original cell outline. x 10

PLATE 4



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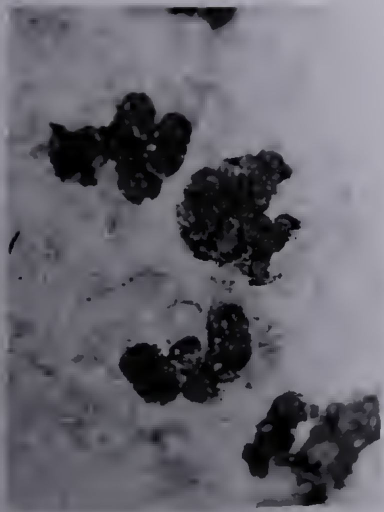

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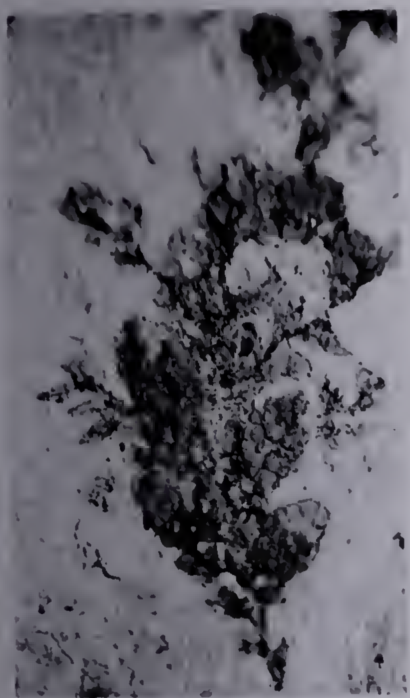

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PLATE 5

Azolla Primaeva (Penhallow) Arnold

Fig. 1 — Dorsal view of vegetative remains from Asp (China) Creek, Princeton, British Columbia. x 5

Fig. 2 — View showing the forward curve of the dosal leaf and the single vascular trace. Note also the root attachment midway between the leaves. (Asp Creek). x 5

Fig. 3 — Megaspores attached to plant axis (Driftwood Cr., B.C.) x 10

Fig. 4 — Axis bearing both megasporangia and microsporangia. Note the megaspore at the base of the microsporangia (Driftwood Cr.) x 10

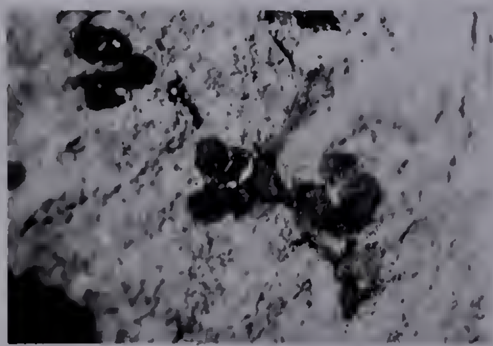
Fig. 5 — Distribution of megasporangia along the entire length of lateral branches. (Driftwood Cr.) x 5

Fig. 6 — Outline of microsporangia and one associated megaspore. Note the microsporangial tip is not unlike that of the modern Azolla x 10.

PLATE 5

1

2



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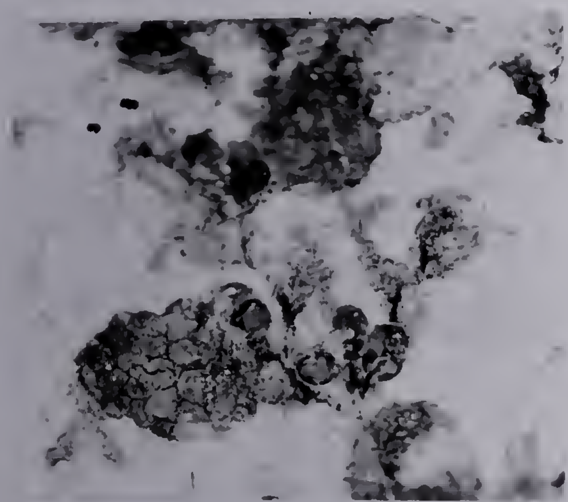

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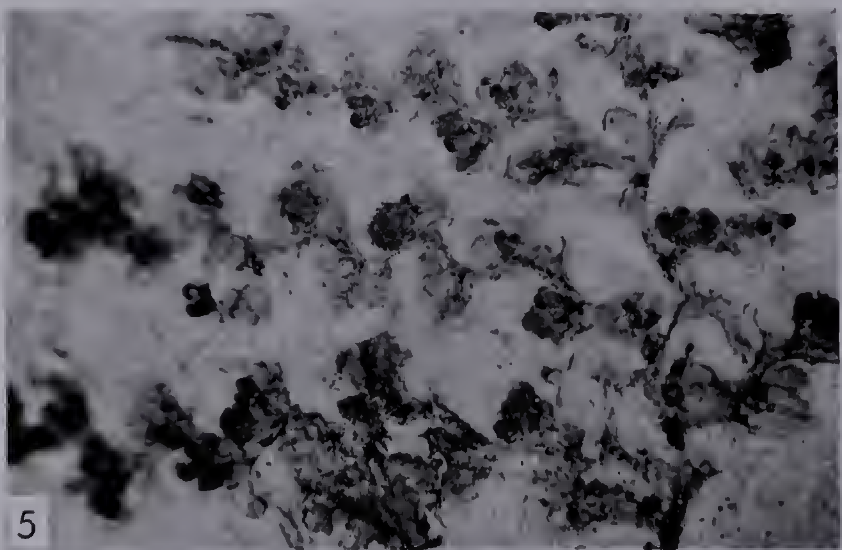

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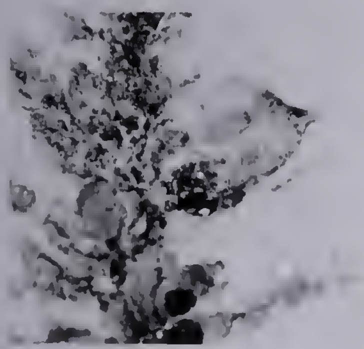

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PLATE 6

Fig. 1	Azolla primaeva (Penhallow) Arnold megaspore; general view. Mag. x 500.
Fig. 2	Deltoidospora sp.; note radial folds and reticulate ornamentation, hi focus. Mag. x 1200.
Figs. 3-8	Verrucosisporites variabilis; n. sp.; 4 and 5 - holotype; 3, 6, 7 and 8 - paratype; 8 - note trilete. Mag. 3, 4 and 7 x 500, 5, 6 and 8 x 1200.
Figs. 9 and 12	Fern sporangia? Mag. 9 x 500, 12 x 1200.
Fig. 10	Cycadopites follicularis; Mag. x 500.
Fig. 11	Cycadopites sp.; Mag. x 500.

PLATE 6

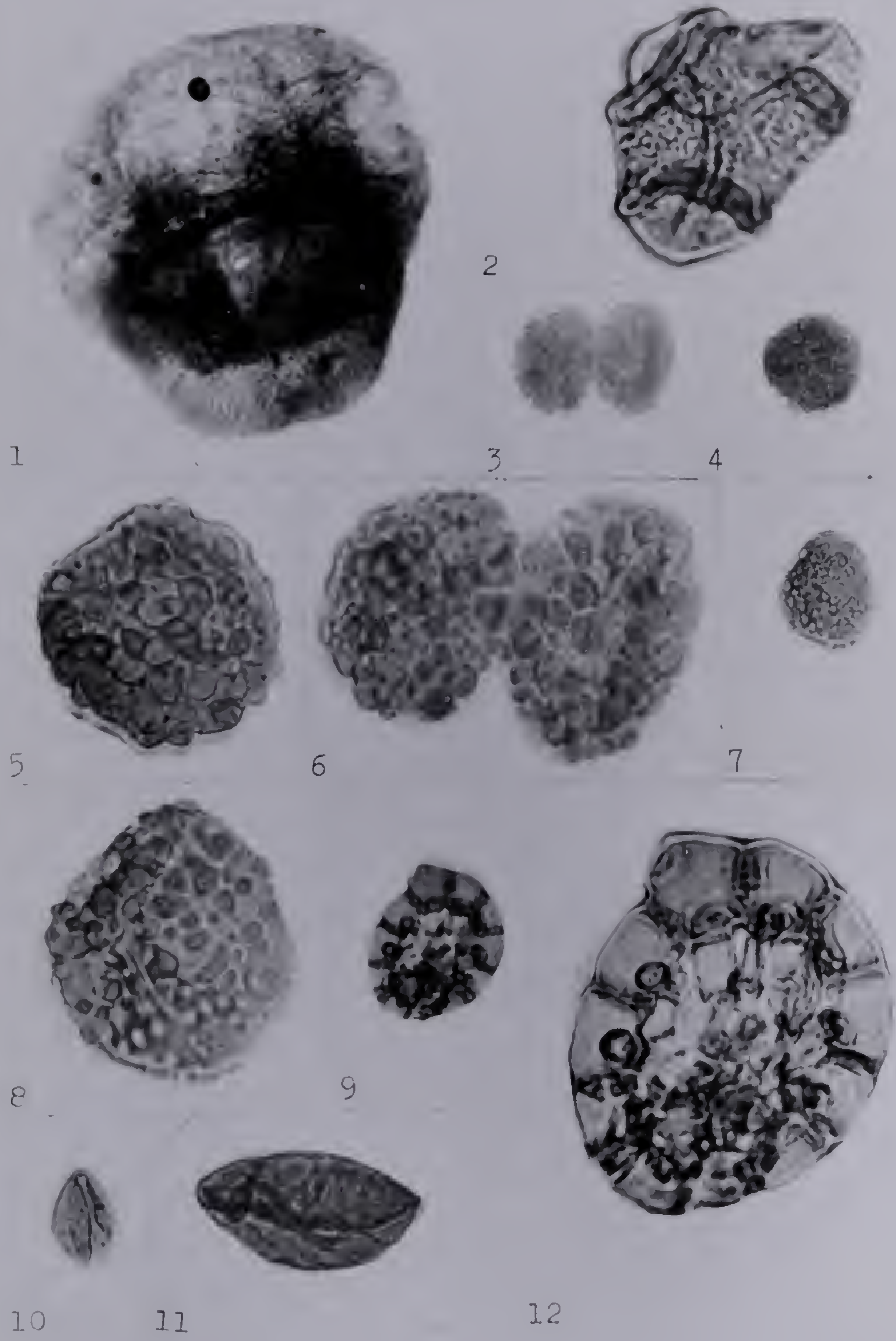

PLATE 7

Fig. 1	Larix plicatipollenites Rouse; general view. Mag. x 500.
Fig. 2	Tsuga viridifluminipites Wodehouse; general view. Mag. x 500.
Fig. 3	Picea cf. grandivescipites Wodehouse; Mag. x 500.
Figs. 4-6	Abietineaepollenites sp. Mag. x 500.

PLATE 7

PLATE 8

Fig. 1	Pityosporites cf. alatipollenites (Rouse) Singh; general view. Mag. x 500.
Figs. 2-4	Pityosporites elongatus n. sp.; 2 - proximal view, holotype; 3 - distal view, paratype; 4 - distal view of specimen from Princeton. Max. x 500.
Fig. 5	Pityosporites magnus n. sp.; equatorial view. Mag. x 500.
Fig. 6	Pityosporites sp. A; proximal view. Mag. x 500.

PLATE 8

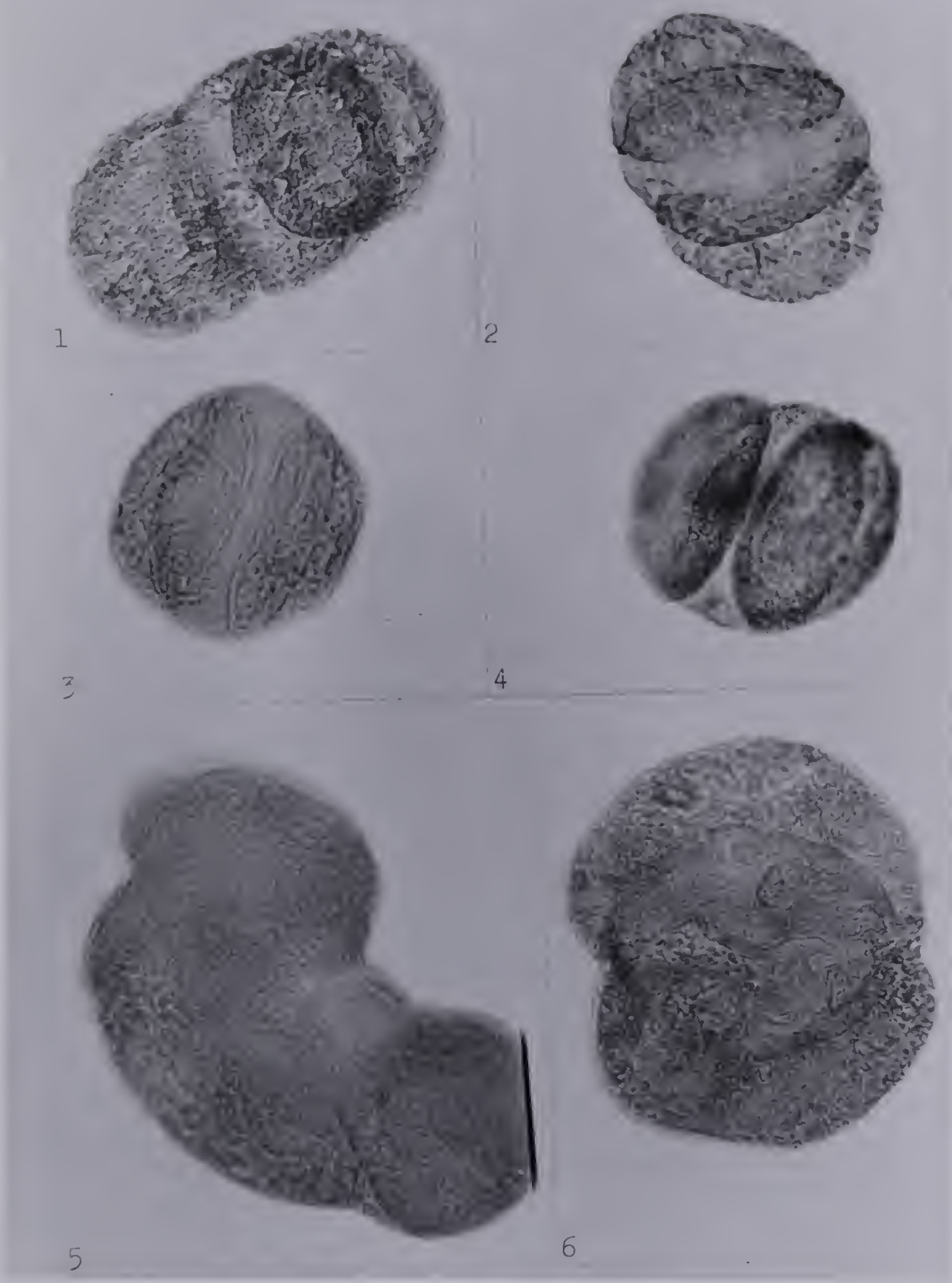

PLATE 9

Figs. 1-2	Pityosporites sp. B; note extreme constriction of the bladders and narrow, short germinal furrow. Mag. x 500.
Fig. 3	Podocarpidites cf. ornatus Pocock; general view. Mag. x 500.
Fig. 4-8	Taxodium hiatipites Wodehouse; note pore at base of rupture and scabrate texture. Mag. 4 and 6 x 500, 5, 7 and 8 x 1200.

PLATE 9

PLATE 10

Fig. 1	Taxodium hiatipites Wodehouse; cluster. Mag. x 500.
Figs. 2-7	Metasequoia papillapollenites Rouse; note pore shape in fig. 5; 6 - distal position of papilla; 7 - note broad base and granular papilla. Mag. 2 and 3 x 500, 4-7 x 1200.
Figs. 8-10	Cunninghamia concedipites Wodehouse; Mag. x 500.
Figs. 11-12	Taxodiaceaepollenites sp.; note undulose exine. Mag. 11 x 500, 12 x 1200.
Fig. 13	Betula claripites Wodehouse; general view. Mag. x 500.

PLATE 10

PLATE 11

Figs. 1-3	Betula claripites Wodehouse; 1 - as fig. 13, Plate 10. Mag. 1 x 1000, 2 and 3 x 500.
Figs. 4-9	Alnus quadrapollenites Rouse; note rectangular shape and arci; note pore, fig. 8. Mag. 4-7 x 500, 8 and 9 x 1200. Figs. 4 and 8 and figs. 7 and 9 are the same specimen, with different magnifications.
Figs. 10-14	Alnus quinquepollenites Rouse; Mag. 11 and 12 x 500, 10, 13 and 14 x 1200.
Figs. 15-16	Carya viridifluminipites (W dehouse) Wilson and Webster; Mag. 15 x 500, 16 same specimen x 1200.
Fig. 17	Carpinus ancipites Wodehouse; note shape of pores. Mag. x 500.

PLATE 11

PLATE 12

Figs. 1-4	*Carpinus ancipites* Wodehouse; 1 and 2 - pore detail and wall structure. Mag. 1 and 2 x 1200, 3 and 4 x 500.
Fig. 5	*Castanea* sp. Mag. x 1200.
Figs. 6-7	*Juglandspollenites* sp.; note shape and position of pores. Mag. 6 x 500, 7 x 1200.
Figs. 8-9	*Carya viridifluminipites* (Wodehouse) Wilson and Webster; note pore shape and thickenings. Mag. 8 x 500, 9 x 1200.
Fig. 10	*Carya juxtaporipites* (Wodehouse) Rouse; general view. Mag. x 500.
Fig. 11	*Platycarya* sp.; note folding. Mag. x 500.
Figs. 12-15	*Pterocarya* sp. Mag. 12-14 x 500, 15 x 1200.

PLATE 12

PLATE 13

Figs. 1-4	*Tilia crassipites* Wodehouse; note pore shape and reticulate ornamentation. Mag. 1 and 2 x 500, 3 and 4 x 1200.
Figs. 5-6	*Tilia tetraforaminipites* Wodehouse; note ornamentation. Mag. 5 x 500, 6 x 1200.
Figs. 7-8	*Salix discoloripites* Wodehouse; equatorial view. Mag. 7 x 500, 8 x 1200.
Figs. 9-10	*Tricolpites scabratus* n. sp.; holotype. Mag. 9 x 500, 10 x 1200.
Figs. 11, 12 and 15	*Acer tulameenensis* n. sp.; 11-12 - holotype. Mag. 11 and 15 x 500, 12 x 1200.
Figs. 13-14	*Acer quilchensis* n. sp.; holotype. Mag. 13 x 500, 14 x 1200.
Figs. 16-18	*Aesculus* ? sp. Mag. 16 x 500, 17 and 18 x 1200.

PLATE 13

PLATE 14

Figs. 1-2	Ericipites sp. Mag. 1 x 500, 2 x 1200.
Fig. 3	Momipites coryloides Wodehouse; Mag. x 1200.
Figs. 4-5	Myriophyllum ambiquipites Wodehouse; Mag. 4 x 500, 5 x 1200.
Figs. 6-16	Pistillipollenites mcgregorii Rouse; note irregular distribution of pila. Mag. 6 and 8-14 x 500, 7, 15 and 16 x 1200.
Figs. 17-18	Potamogeton holickipites Wodehouse; general views. Mag. x 500.

PLATE 14

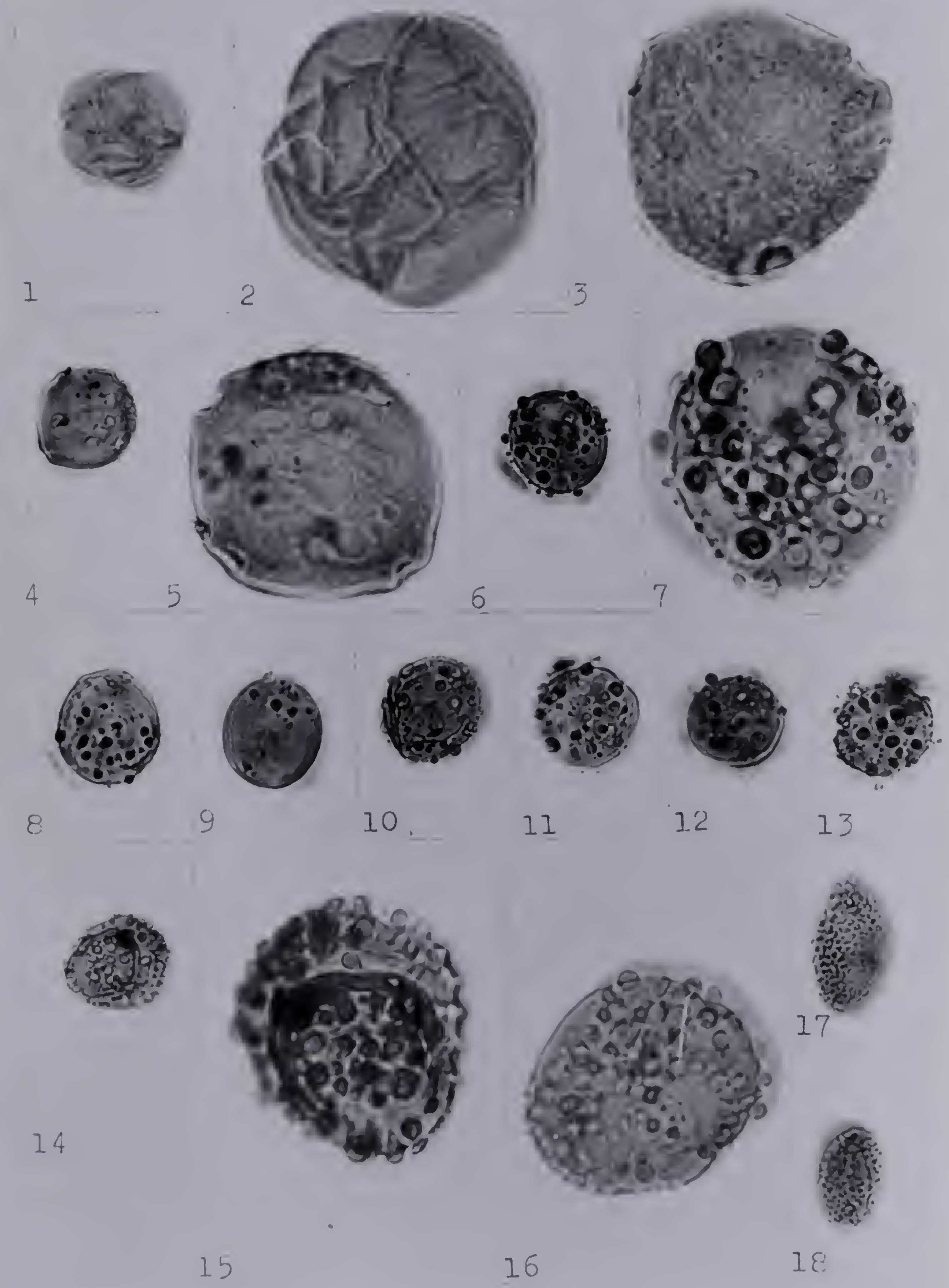

PLATE 15

Figs. 1-2	Potamogeton hollickipites Wodehouse; Mag. x 1200.
Fig. 3	Sabal granopollenites Rouse; Mag. x 1200.
Figs. 4-7	Psilodiporites krempii Varma and Rawat; 4 and 5 - from Coalmont; 6 and 7 - from Princeton Hills M.Sc. thesis. Mag. 4, 6 and 7 x 500, 5 x 1200.
Figs. 8-9	Tricolporopollenites sp. Mag. 8 x 1200, 9 x 500.
Figs. 10-12	Triporopollenites sp.; 10 - note pores; 11 - verrucate ornamentation. Mag. 10 and 11 x 1200, 12 x 500.
Fig. 13	Triporopollenites cf. formosus; note bifurcation at base of pore. Mag. x 1200.
Figs. 14-15	Polycolpites sp. Mag. 14 x 500, 15 x 1200.
Fig. 16	Unidentified fungi? Mag. x 500.

PLATE 15